A33

The Kent Incorporated Society for Promoting Experiments in Horticulture

ANNUAL REPORT

1949

EAST MALLING RESEARCH STATION

Near MAIDSTONE KENT

1st January, 1949 to 30th September, 1949

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THE SPENCER MOUNT MEMORIAL GATES AT BRADBOURNE

[frontispiece

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THE KENT INCORPORATED SOCIETY
FOR PROMOTING EXPERIMENTS IN
HORTICULTURE

ANNUAL REPORT

(THIRTY-SEVENTH YEAR)

1949

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KENT

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The correct abbreviation of the title of this Report *is :—*
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Tours of the Station are arranged by appointment on Tuesday and Thursday afternoons. Visitors with special interests are received by appointment on the mornings of these days and may then join the general tour later if they wish. Wednesdays and Fridays are reserved for visiting research workers who also should make an appointment to ensure that a useful programme for the visit can be prepared.

All visitors wishing to see the work of the Station should go to the Enquiry Office at the Research Laboratories.

Visitors coming by road should take the turning to East Malling, opposite "The Bull", Larkfield, on the main London-Maidstone road. The entrance gate to the Research Station is on the left, opposite the "King and Queen" in East Malling.

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FOREWORD

The Administrative Report of the Station, previously known as the Supplementary Annual Report, was despatched to Members during May. Attention is drawn to the fact that both the present Research Report and the Administrative Report cover the nine months from the 1st January to the 30th September only. In future, both Reports will cover the financial and academic year from the 1st October to the 30th September.

The arrangement of this Report follows that of previous years. Details of the working of the Experimental Farm will be found in Section I, in which attention is drawn to the problem of providing sufficient suitable land for the ever expanding programme of field experiments. Information as to research projects in hand and their progress is given in Section II. This year, the summaries of papers not readily available to Members, previously included at the end of each sectional report, have been omitted. Important results described in such papers, however, are now incorporated in the text with a reference number (e.g. E.310) to the list of titles at the end of the sectional report. Section III consists of twenty-three papers covering a wide range of subjects describing the results of recent experiments. The text of the second Amos Memorial Lecture, in memory of the late Mr. Jesse Amos, is also included. Section IV consists of Bulletins written in less technical language. Readers who are interested to follow up the progress of the work described in them should consult the descriptions of work in hand given in Section II.

Section I

THE EXPERIMENTAL FARM

By F. H. VILLIERS, with contributions from F. H. BEARD and T. V. DIXON

Until midsummer, 1949 looked like being a very satisfactory year for growers of both top and soft fruits. After moderate crops and an " off " year for some apple varieties in 1948 there was every prospect of an excellent fruit harvest. There had been a favourable blossoming season with no severe damage from May frosts, and most fruit blossom had set sufficiently well for a really good crop ; only average rainfall was needed for these high hopes to be realized. Average rainfall, however, was not forthcoming, and the drought which followed with its disastrous effect on fruit size and quality will long be remembered by Kentish fruit growers. A severe attack of red spider which developed at East Malling late in the summer did not help matters.

The story of 1949 is not one of unrelieved gloom, however, for though apples and pears suffered severely from the drought, cherries generally were a good crop, and soft fruit crops, though a good deal lighter than in 1948, were satisfactory. The open dry autumn and winter were excellent for nursery work and the sunny summer made the harvesting of the arable crops easy.

Blossoming and picking dates did not vary much from the average at East Malling, for though there was a short warm spell during the third week of March (when the Myrobalan plums were in full bloom) the weather soon became colder and cherry and plum blossom was not fully out until the normal time. A second and longer very warm spell which occurred during the later half of April brought the apple blossom out very quickly. The speed with which the apple blossom opened made it difficult to get round quickly enough with the second pre-blossom lime sulphur scab spray and certain early varieties, e.g. Beauty of Bath and Duchess Favourite, had to be missed.

Cherry picking started on 6th June, three days later than in 1948, and apple picking on 4th August. This was somewhat later than usual, but the drought was beginning to have an effect and our early cooking apples did not swell up sufficiently to be marketable before that date.

Experimental Orchards.—Top Fruits.

Apples.—The 1949 apple crop at East Malling was most disappointing ; only 13,824 bushels (40 lb. to a bushel) were marketed, 359 bushels less than in the previous year, and only just under two-thirds of the 1947 crop. The severe drought was almost entirely responsible for this, for though the number of individual apples was sufficient for a heavy crop they were so small that many more were required to fill a bushel box ; many were under $1\frac{1}{4}$ in. in diameter and were unmarketable. All varieties were affected to a greater or lesser extent, particularly those which set the largest number of fruits. In order to ensure uniformity in experimental treatments it is seldom possible to thin fruit more drastically than to singles at this Station and this proved quite inadequate for such varieties as Miller's Seedling and Worcester Pearmain, which set very heavily here in 1949. The total quantity of Worcesters marketed was 2,576 bushels, some 1,500 bushels less than the average of recent years. This is accounted for partly by the grubbing of one-third of an acre of trees of this variety on the old pruning plot in Great East Field, but mainly by small fruit size. Samples from representative plots showed that the fruits were running about 10 to 12 to the pound instead of our usual $5\frac{1}{2}$ to 7 to the pound. The same was also true of our Miller's Seedlings, Laxton's Superb, Barnack Beauty, Lord Derby, Grenadier and Early Victoria.

Cox's Orange Pippin, with a total crop of 1,469 bushels, gave a few bushels more than in 1948 and the fruit, though poor, was not so small as the varieties mentioned above. A relatively light " set " apparently enabled the trees to collect sufficient moisture to swell the crop to something like normal size. The crop of Bramley Seedling, 4,052 bushels, was also greater than in 1948 which was a partial " off " year for this variety here. Picking was delayed until mid-October in the hope that autumn rains would come in time to benefit the crop ; this in fact happened and the fruit swelled considerably during the last fortnight, greatly increasing the yield, but also, unfortunately, causing some fruits to split.

Our other principal variety, Lane's Prince Albert, yield 1,121 bushels, did reasonably well, but here again more drastic thinning would have been advantageous.

Pears.—There are now only two plantations of mature pears on the Research Station: the original trial of Conference on quince rootstocks on Egham Field and the trial of Dr. Jules Guyot and Reine des Poires on clonal pear rootstocks interplanted with apples in Church Fields. The yield from these and the two young double-working trials, mostly Williams' Bon Chrétien, also in Egham Field was 1,019 bushels (48 lb. to a bushel). Almost half the fruit, 443 bushels, came from the Dr. Jules Guyot trees, which gave an average of just over three bushels per tree, one of the best crops since they were planted in 1927. The crop of Conference, 185 bushels, was very badly affected by drought; there was a heavy set of fruit but, by the time the crop was mature the full effect of the water shortage was apparent on these close planted trees and much of the fruit was so small as to be unmarketable.

Cherries.—Fortunately the cherry crop at East Malling was not much affected by the drought. The rain which fell in May was apparently sufficient for the needs of the developing fruit, and although many of the trees wilted later in the summer, a good crop of fruit was gathered before they displayed any signs of water shortage. The total yield of sweet cherries was 2,311 halves (24 lb. to a half sieve), 220 halves more than in 1948. The bulk of the fruit again came from the six acres rootstock trial in Churchfields, where the varieties are Early Rivers, Bigarreau de Schrecken and Turkey Heart. In recent years the crop of Early Rivers has always been considerably larger than that of Bigarreau de Schrecken or Turkey Heart from approximately the same number of trees; in 1949, however, some of the lower blossoms on the drooping branches of the Early Rivers trees were damaged by a frost which occurred in May and Turkey Heart was the heaviest cropper with Bigarreau de Schrecken a poor third. Although the crop of Bigarreau de Schrecken was light the fruit was of exceptionally good quality and sold well. The total crop from the six acre rootstock trial, now 21 years old, was 1,407 halves or just over 234 halves per acre. On the Variety Collection the average yield was only just over 100 halves per acre, but it must be borne in mind that many of the trees have only recently been planted and that several of the older ones are Mazzards which are seldom worth picking.

The crop of acid cherries was slightly heavier than in 1948, i.e. a total of 237 halves from 105 trees of Morello and 57 Kentish Reds.

Plums.—In spite of the dying back of young shoots mentioned later in this report, there was plenty of plum blossom and all varieties at East Malling set well. The total crop marketed in 1949 was 3,032 halves (28 lb. to a half sieve) compared with 2,138 halves in the previous year and would almost certainly have been nearly double that figure had it not been for the drought. The Cherry Plums in the windbreaks set exceptionally heavily and bore an enormous number of fruits, but very few of these grew to any size and at picking time were much more like cherries than plums. A total of 459 halves was marketed and almost an equal quantity on the older trees wilted before they were ripe and the fruit was not worth picking. Much the same is true of the varieties Victoria and Warwickshire Drooper; the quantity of fruit marketed, 1,229 halves of Victorias and 192 halves of Warwickshire Drooper, was only about half what there would have been had there been average rainfall. Many of the fruits failed to mature properly and much of what was picked was of such poor quality that it was quite unsaleable. Our Czar plums, of which 403 halves were marketed, were also small, but this was not surprising as many of the trees are used as windbreaks. However, although small, most of the fruit was saleable as it was not shrivelled, as was much of that of the later varieties.

Our collection of gages and gage plums on Deadman Field, now 11 years old, did not suffer much from the drought, as many of the trees are not yet in full bearing. The crop, though by far the best to date, was not heavy and the trees were able to mature their fruits in spite of the low rainfall. Indeed, much of the crop was of excellent quality for there was very little fruit splitting, a trouble which has caused severe loss on some varieties in wetter years.

Small Fruits.

Black currants were again disappointing at East Malling. As mentioned in last year's Report, the bushes were exceptionally well grown and well furnished with young fruiting wood; there was plenty of blossom but, as in previous years, much of this " ran off " and the total crop from the 4 acres of mixed varieties on Merryweather was only just over $3\frac{1}{2}$ tons. Admittedly there are several " passenger " varieties which are now seldom planted commercially, but even so the crop was a poor one. The field has a slight slope to the north and the Myrobalan hedge planted as a windbreak is not yet large enough to afford much shelter, so it is possibly cold winds at blossom time that have been responsible for our poor yields.

Loganberries were also disappointing. The crop from the one acre of manurial and training trials was only just over 30 cwt., not nearly enough to offset the cost of cultivation, training and manuring. Again in 1949, much of the cane, which looked promising in the autumn, died back before training time in the spring. There was not sufficient frost to have caused this and it is difficult to explain why it should have happened. It is just possible that rust from the training wires may have had some toxic effect, and this is being investigated.

Raspberries again cropped reasonably well and yielded nearly 6 tons from just over 4 acres of mixed varieties of all ages. This was slightly less than was obtained in 1948 from a larger area, but many of the later fruits shrivelled up as a result of the drought.

The strawberry crop was a poor one ; only 24 cwt. of poor quality fruit was marketed from the 1¼ acres grown. A few of the early blossoms were killed by frost, but the chief reason for so small a crop was lack of moisture. Many of the plants wilted badly and a small watering trial showed that irrigation would have paid handsomely had it not been undesirable from the experimental point of view.

Fresh Plantings, Grubbings, etc.

The problem of providing land to meet the needs of an ever expanding research programme is now becoming acute. Much of the open land on the Bradbourne estate and elsewhere, suitable for fruit, has been or will be planted with trees during the next three or four years. It has, therefore, become an urgent matter to free land for future needs, and plantations which, although they are still producing good crops of fruit, have outlived their experimental usefulness, are gradually being cleared.

Between the years 1945 and 1948 most of the fresh planting has been concerned with the establishment of new plantations of top fruits, primarily for the Pomology Section ; that is, for further rootstock, pruning and variety trials. In 1949 a start was made to provide for the future needs of the Pathology Section, and in the autumn two acres of dwarf pyramids and rootstocks were planted on Plot 20 for future fungicide work. In addition, about 16 acres on Park Farm have been set aside, and some planted, to provide material for the future work of the Pathology, Entomology, and Plant Protective Chemistry Sections. Further, ¼ acre of selected apple and pear seedlings were planted for the Plant Breeding Section, together with ½ acre of apple and quince rootstocks to be grown up into frameworks on to which the best of the new seedlings can be worked in due course. A further small area of apples was also planted on Larkfield for future cover crop experiments, and ½ acre of Victoria plums on Deadman Field.

The largest area grubbed in the autumn of 1949 was the Bramley Seedling plantation in Kiln Field. These 30-year-old trees, at 24 ft. square, were too big and too crowded to be of any further experimental value. Whilst their going will mean a serious loss of revenue, 4 acres of valuable land, near the laboratories, will be made available for further trials when uniformity of soil conditions has been sufficiently restored. The opportunity is being taken to determine the most effective and speedy methods of achieving this end.

Approximately ½ acre of Victoria and Czar plums on Deadman Field and most of the remainder of the old apple pruning trial on Great East Field were also grubbed. The Early Victorias on the " Pruning Plot " were kept because they provide the only remaining demonstration at the Research Station of the variability of trees grafted on seedling rootstocks. Other Plots cleared include the remainder of the Lord Derby trees on Kiln Field, the red currant variety collection at Bradbourne, the oldest trial of Mr. Grubb's seedling raspberries on Newgates Field and the last of the blackberry seedlings on Plot 18. The Lord Derby trees in the rootstock trial in Egham Field were cleared to make more room for the adjacent plums. It may be remembered that when the Bramley's Seedling trees were grubbed from between the Worcesters in the rootstock trial on Plot 12 in 1934, their places were filled by fourteen-year-old Worcesters transplanted from a nearby plot. At 15 feet square, the trees on this plot, especially those on vigorous rootstocks, had become overcrowded and the transplanted trees were removed to give the original thirty-year-old rootstock trial trees sufficient room.

As related later in this Report, cultural experiments on hops are being transferred to Wye College after this season and accordingly during the winter 1949-50 all the hop gardens (10 acres) except a small area in Bullion Hop and Brewer's Gold and those devoted to Pathology trials, will be grubbed. While it is with regret that we record the termination of the hop cultural trials at East Malling after some 35 years, the land thus made available will certainly be of value for fruit plantings.

Routine Spraying Programme.

The winter-wash programme carried out in 1949 was very similar to that followed the previous year. All pears, peaches, cherries, and black currants were sprayed before Christmas with 5 per cent. Tar Oil, and all apples and plums with 4 per cent. DNOC ; the chief difference was that no DDT was added to the DNOC this year as the 1948 application proved so effective in controlling Apple Blossom Weevil that it was not considered necessary to take any special measures to deal with this pest. All raspberries were sprayed with 5 per cent. Tar Oil in an attempt to control the aphid vectors of some of the virus diseases.

Although spraying conditions throughout the season, as a whole, were ideal, a spell of snow and frost during the first fortnight of March made it difficult to finish the DNOC application. Nevertheless, this was completed in good time, by 12th March, and no damage that could be definitely attributed

to the spraying was recorded. Plums and gages sprayed with 4 per cent. DNOC on 15th and 16th February suffered from the dying back of numerous one-year-old shoots. It is possible that this was due to over spraying or to spray drift falling on shoots on which the first coat of wash had already dried. This is by no means certain, however, as the same plums had received similar treatment in previous years without any bad effect, and bud damage was common on many fruit plants following the mild winter. In any case, the gages yielded well.

Capsid and caterpillar were again completely controlled by adding 0·1 per cent. DDT to the green-cluster lime-sulphur scab spray. Apple Scab was generally less prevalent than in the previous year, doubtless due to the dry weather, and a good measure of control was achieved on all plots. All varieties were sprayed twice with lime-sulphur pre-blossom, and after blossom, Cox was sprayed twice with dispersible sulphur, and other varieties (except sulphur-shy sorts) once with lime-sulphur and once with mercurated lead arsenate. It was thought that by using this latter combined fungicide and insecticide at this stage, it might be possible to get a better control of Codling Moth, as there would be some lead arsenate already on the fruit to kill any early hatched larvae that might otherwise have entered the fruit before the routine lead arsenate spray was put on.

Mercurated lead arsenate was used this year instead of straight lead arsenate for the routine Codling spray in an attempt to check also late Scab infections which have proved troublesome in recent years, especially on Bramley's Seedling. There certainly was less late Scab in 1949 but it is uncertain whether this was due to the dry weather or to the mercurated lead.

The inclusion of 2 lb. of derris and a spreader in the second post-blossom Scab spray and in the Codling spray did not give effective control of red spider. Questions of formulation probably account for this.

Cherries and pears received the recommended routine sprays ; copper sprays were used on cherries for the control of Bacteriosis, and dispersible sulphur post-blossom on pears for Scab instead of Bordeaux mixture, as both of these preparations are so much easier to handle and to apply.

Black currants were sprayed three times during the summer. Once with 2 per cent. lime-sulphur against Big Bud Mite and twice with 0·1 per cent. DDT to control Black Currant Leaf Midge ; both pests were successfully controlled. In the case of raspberries, two gammexane sprays were used instead of DDT for Midge control as DDT did not give very good results in 1948 ; gammexane certainly seemed to be more effective.

Loganberries were sprayed in accordance with the recommendations of the Spray Calendar and a clean crop resulted.

Arable Crops.

There were only 131 acres under arable crops in 1949 ; this was 11 acres less than last year, fresh plantings of fruit having exceeded the ground cleared by that amount. The fine dry summer made harvesting of hay and corn crops easy, but the potatoes and root crops suffered severely from lack of rain.

Potatoes.—Altogether 24 acres of potatoes were grown : 10 acres of Majestic, 9 acres of Arran Consul and 5 acres of Stormont Dawn ; all varieties were very badly affected by the drought. In spite of the fact that planting was completed by mid-April, and most of the land was dunged, the average yield was only some 6½ tons of ware per acre, and a large proportion of the tubers were small and misshapen. Stormont Dawn seems to suit this land and appeared to withstand the drought, if anything, rather better than either Majestic or Arran Consul.

Peas.—Nine acres of Lincoln peas were grown for canning, but these too suffered from lack of rain and the average yield was only just over 1 ton of shelled peas per acre. However, the weather was good at harvest time, the crop was quickly cleared, and showed a reasonable profit.

Cereals.—Barley was the outstanding arable crop at East Malling in 1949, the 25 acres of Plumage Archer grown averaged almost exactly 7½ qrs. per acre, all of which was harvested in excellent condition. This barley was all sown between 17th December and 20th December, although the soil was so wet at the time that one field had to be sown broadcast and cultivated in afterwards. It would appear that barley will stand, and thrive, in much wetter soil conditions than indicated by the time-honoured injunction to " Sow Barley in Dust ".

Wheat also yielded well ; 13 acres of Holdfast and 19 acres of Squarehead 13/4 averaged 7 qrs. per acre. The Holdfast yielded most heavily but was not such a good sample as the Squarehead, most of which was threshed early and sold for seed.

Haymaking was easy in 1949 and of the 27 acres of 1 year ley grown, 20 acres were made into first-class hay. The areas of ley were rather small and at some distance from the stockyard, so it was not possible to make full use of our hay sweep this year. The small " experimental " grass silage clamp made in 1948 proved so successful that it was decided to make more silage this year and the whole of

the remaining 7 acres of ley was conserved in this way. The resulting product appears very satisfactory and is certainly relished by our bullocks. Approximately 6 acres of kale roots were also grown for the latter, which again did well.

F.H.V.

Hops.

The open winter weather enabled cultivations etc., to be carried out well to time. In the early part of the season growth was good, but later the prolonged drought conditions had their effect and growth was well below average. As might be expected, Downy Mildew was at no time much in evidence and only the Goldings at Bradbourne had many " spikes ". The dry and warm season favoured the spread of red spider which at one time appeared to be a serious menace. However, good control was obtained with one of the new phosphorus insecticides and the crop was picked free from spider damage.

Drought reduced the yield of practically all varieties. The reduction was very large when measured by bushels, but as the hops " weighed well ", needing relatively few bushels of green hops to give 1 cwt. of dried, the yields per acre were rather better than might have been expected. The total crop amounted to just over 5¼ tons, the lowest since 1941, and about 2 tons less than in 1948. Valuations are not yet to hand, but analyses have shown nearly all varieties to be considerably higher in P.V. than in 1947.

The nursery plot was on a reduced scale and was mainly used for the production of Fuggle sets for the Pathology Section, together with sets of certain of the new seedling varieties for the establishment of new plots at Wye.

F.H.B.

Experimental Nurseries.

The hot, very dry, summer made things particularly difficult for the nursery staff in 1949. It was necessary to water all the black currant cuttings quite early in the spring to prevent their being completely dried out, loganberry tips were watered at planting time and the parent loganberry plants later in the season with a rotary sprinkler to encourage the production of new growths. Mortality was heavy amongst our bedded stocks, largely as a result of lack of moisture, and maiden trees only grew away after a slow and difficult start. However, stocks lined out for bedding established themselves satisfactorily and the bark " ran " well following a slight rain. A good bud take resulted and very little grafting of failures will be necessary next spring.

Altogether some 8,500 maiden fruit trees and 10,500 certified two-year-old black currant bushes were raised in 1949. In addition, smaller numbers of loganberry tips, " Black-Red Hybrid " raspberry plants, red currant and gooseberry bushes were produced, largely for experimental needs. After meeting experimental requirements the only strawberry runners available for distribution were some 40,000 Auchincruive Climax M.46.

Pests and diseases this season have been few and were easily dealt with by using the recommended routine sprays. The Black Currant Leaf Midge (*Dasyneura tetensi*), however, gave some trouble, but three applications of 0·01 per cent. parathion, each given as soon as the first larvae of a new brood were observed, gave good control on most varieties. In the case of Mendip Cross, however, results were not quite so good and some curling of the leaves resulted, possibly because the extra thickness of the leaf or the more compact growing tip prevented the wash reaching the larvae.

Continuing the policy outlined in last year's report, the planting of the new stool-bed of Woolly Aphid resistant stocks was completed in the early months of 1950 and a further area of the old commercial stool-bed of Malling varieties was grubbed. The new resistant stocks, planted early in 1949, established themselves well in spite of the drought and all varieties appear to have developed good root systems ; this new stool-bed now covers nearly 6 acres, including headlands.

Rooting was satisfactory in the established stool-bed of standard varieties and a total of 518,500 stocks of saleable grades was harvested. The weather in the autumn was ideal for lifting nursery material and most of the work was completed well before Christmas. Casual labour has been used in the past few seasons to help speed up this work, but it is questionable if this is really worth while, for, unless there is very strict supervision, much damage can be done to the stool and layer-beds. Among apple stocks, M.IX did particularly well in the hot dry summer ; the cherry Malling F12/1, however, did poorly and production was not up to expectation.

In addition to the material already mentioned, scion wood of the new apple variety " Tydeman's Late Orange " and one-year bushes of " Amos Black " black currant were distributed for the first time to as many members as possible.

T.V.D.

Section II

GENERAL REVIEW OF RESEARCH WORK
WITH LISTS OF PAPERS PUBLISHED DURING THE YEAR

I. POMOLOGY

By W. S. ROGERS

A.—Tree Fruits.

The Pomology Section has over 120 tree-fruit projects in progress. This reflects not only the importance of the problems of tree-fruit growing, but also the fact that, as trees are long-lived, it is essential to continue certain experiments for many years. But there is neither the space nor the need to mention each project in every annual review ; and stress will, therefore, be laid on those in which new information of special interest has become available during the year.

Rootstocks.

The older rootstock trials of apples, pears, plums and cherries again cropped heavily, though " frost eye " and " frost rings " were found on some of the apples.

The younger trials, including the series of new apple rootstocks tested for resistance to Woolly Aphid, and the other series, the " Nine Crosses " (rootstocks bred at East Malling using M.IX as one parent, and covering a wide range of vigour) also did well. Both series are established in full-scale field trials, and the Woolly Aphid resistant stocks, carrying the scion varieties Cox's Orange Pippin, Jonathan and Ellison's Orange, bore useful crops for the second year running at five years old. Jonathan, which was chosen for its international interest, has been outstanding for its precocity, and appears to be a valuable variety for rootstock trials in which early and regular crops may give a quick indication of rootstock effects.

In the gage plum rootstock trial, now 9 years from the bud, trees on Myrobalan B again gave the heaviest crops. Denniston's Superb on Myrobalan B bore 120 lb. and Early Transparent on Myrobalan B 98 lb. per tree.

A new semi-dwarfing rootstock trial of plums has been planted with the four scion varieties Cambridge Gage, Early Laxton, Victoria and Marjorie's Seedling. In the first summer after planting many of the trees of Marjorie's Seedling carried some fruits.

In December, 1948, a trial of the varieties Williams' and Conference on a series of 8 clonal pear rootstocks, with Quince A as a control, was planted. The trees were already three years old. Two of the rootstocks, C7 and C8, had previously been tried under Dr. Jules Guyot, in trees now 25 years old. C8 had produced a comparatively small tree giving a very poor crop. C7 had given a rather vigorous tree and cropped much more heavily. The other pear stocks had been selected for their behaviour in the nursery and on the basis of root structure indicating a probable range of vigour. A surrounding guard row was planned as a subsidiary trial using five other pear stocks and Quince A.

Histological Investigations.

Records have been made of the vegetative growth of double- and single-worked pear, plum and peach trees for studies of compatibility between rootstock and scion. Three nursery trials of pears, plums and peaches have been grafted for further studies of compatibility. Interspecific and intergeneric grafts using various types of Malus, Pyrus and Cydonia have been made for an examination of the structure of the unions.

Approximately 1,000 permanent sections of scions, rootstocks and graft unions of pears, plums and peaches have been prepared for studies of histological structure in relation to compatibility, and measurements made of the amount and distribution of different cell types. Trees from the same series have been used for an examination of the amount of starch in scion and rootstock. A macroscopic examination has been made of longitudinal sections of a similar series of older trees.

The histological structure of graft unions in trees of Conference, Quince A and pear rootstock C8 grafted together in various combinations has been examined macroscopically and simple microchemical

tests made to indicate the variation in starch content of the different component parts of the tree. These observations have been related to records of growth and fruit bud formation and a paper prepared on the results.

Priestley's bark stripping technique has been used to study the progress across graft unions of the stimulus causing the initiation of cambial division in spring. Graft unions did not appear to retard the progress of the stimulus, even where the components of the tree were incompatible and there was considerable obstruction to translocation across the union.

During the summer of 1949 monthly records were made of the initiation of phloem necrosis in the incompatible combination Hale's Early peach on Myrobalan B.

A series of apple, pear and plum trees on their own roots are being raised for use in compatibility studies.

The reciprocal effect of the scion and the rootstock on their histological structure is being studied in (1) a series of apple varieties and rootstocks grafted on Crab C and (2) apple varieties on a range of rootstocks.

An examination was made of the root systems of some Bramley's Seedling apple trees to discover the extent of the scion-rooting that had occurred. The structure of the scion roots was compared with that of the rootstocks.

The root structure of a collection of three-year-old American Myrobalan seedlings was examined. Most of the seedlings seemed likely to prove vigorous as rootstocks and no really dwarfing types were found in the series.

The strawberry pot plants grown to investigate the effect of different treatments on mycorrhizal development have been examined and the trial concluded. A new trial on similar lines has been begun.

New Plantations.

Trees on the two new plantations, Churchfields (loam) and Larkfield (sand), established during 1945 and 1946, made satisfactory growth in 1949 in spite of the dry summer. Trees on Larkfield plantation showed severe drought symptoms, especially on the Bearsted Series gravelly sand. Much leaf yellowing and leaf fall were seen, but the scorching and shoot dieback recorded during the summer drought of 1947, when the trees were only two years old, did not recur.

The planting up of the remaining part of the new apple variety trial, in 1949, completes the establishment of the Churchfields plantation. Tydeman's new varieties, Michaelmas Red, October Pippin and Martinmas, together with Ellison's Orange as a standard mid-season variety, were planted, mainly on M.II and M.VII. One row of trees is receiving very light pruning so that the natural habit of these new varieties may be observed.

Propagation.

The vegetative propagation studies are continuing in close collaboration with the Physiology Section (see IIIA).

An expedition to Holland to survey current research in vegetative propagation and nursery techniques with special reference to soil water relations, growth substance treatments, rootstock propagation and plant certification schemes established useful contacts with workers in these fields.

A detailed description of the terraced island constructed in the Bradbourne Lake for experimental work with cuttings has been published (E.310).

The nursery testing of rootstocks for ease of propagation and compatibility with selected indicator scions continues. Amongst the plum rootstocks undergoing test are two vegetatively propagated Myrobalans. One comes from the U.S.A., and so far appears to behave much like our Myrobalan B in its compatibility with common scion varieties, but is of even greater vigour ; the other is from Belgium and is reported to have a wider compatibility range, a valuable asset particularly when coupled with the ease of propagation associated with Myrobalan.

Continuing the search for better cherry rootstocks two selected Mazzards have been obtained, from North-West Germany, reputed to be highly resistant to Bacterial Canker. These will be propagated and tested alongside our own clones.

A small weedkiller trial was carried out in a rootstock layer bed (see p. 24).

Double-working.

A series of cherry trees has been raised by double-working potentially incompatible rootstocks using intermediates of wide compatibility. These trees will be tested in the field.

A pear and a plum used as stem-builders on the Continent have been collected for nursery trial.

The Williams' Bon Chrétien pears on quince, now eight years planted, which had their unions bridged when two years old, have grown and cropped as well as double-worked ones.

Cover Cropping.

In the long-term ley experiment, which includes a series of plots under grass since 1940, the performance of the trees during the 1949 drought was very satisfactory. In the first seven seasons of this trial (E.301), grassing-down, by reducing the amount of " pre-harvest drop ", while maintaining the total crop equal to that under cultivation, resulted in an increase in the amount of picked fruit, while the fruit colour was also improved. It was concluded that the successful management of grassed orchards depends on (*a*) avoiding vigorous grasses in the seeds mixtures, (*b*) frequent mowing, and (*c*) the application of adequate artificial nitrogen. In this trial, the use of sulphate of ammonia, although necessary for the trees, resulted in elimination of clover from the sward ; a further experiment showed that this effect was independent of the form in which artificial nitrogen was used or the time of year at which it was applied (E.302).

Changes in sward composition in this long-term ley trial suggested that it may be unnecessary to sow complex mixtures. Turning attention to the possibility of using simple mixtures, the number of small " museum " or observational plots has been greatly extended in order to make a preliminary study of single grass species, including fescues, alone and combined with wild white clover.

The new cover crop trial on the sandy soil at Larkfield has already given interesting results. The dry spring and summer were not propitious for sward establishment, but the drought also accentuated the checking effect of the weeds which developed, and striking contrasts were seen between the vigour of these young trees in the presence and absence of sward competition. Grassing-down of two-year-old trees would not, of course, be recommended as a commercial practice, but in this trial extreme conditions are being studied. Among the soil effects under observation are those concerned with structure and with erosion. In the first year of the trial the use of cover crops has shown improvements in soil structure.

In the present state of knowledge of orchard soil management practices, although grass swards are found to be very useful for established orchards, it is considered advisable to use only autumn and winter cover for young trees, in order to eliminate summer competition. For this purpose, oats and tares are found to be satisfactory. In an attempt to find suitable alternative autumn annual cover crops, a new trial is in progress, comparing ten different cover crops, including several legumes alone and in combination with Italian rye-grass. These plots have been deliberately sited in a loganberry plantation where it is known that conditions are severe for cover crop growth, owing to trampling during training of the cane and to the high local weed seed population, but they may suggest suitable annual cover crops for tree fruits.

Inorganic Fertilizers.

Both the long-established inorganic manurial trials are being continued. As with other investigations, 1949 gave an opportunity to study the reactions to drought conditions of trees under different treatments.

Soil Moisture.

Further tensiometer records have been made. In addition to continuing observations in existing sites, a preliminary study has been made of water conditions in the terraces of the Bradbourne lake delta. Soil samples taken from the Larkfield cover crop trial showed the effect of weeds in drying out the soil. A new model tensiometer, specially designed for research purposes, appears to be satisfactory under test, and it is hoped to use this in a trial involving contrasting soil management practices.

Soil Analysis.

Further soil organic matter determinations have been made in connection with cover cropping investigations. Soil structure changes are being investigated by the wet-sieving technique, which shows the proportion of water stable aggregates, and this work is yielding interesting results. Some routine chemical analyses have kindly been carried out by the N.A.A.S. The recent acquisition of a pH meter will help considerably in studying the effects of manurial and other treatments on soil conditions and the effects of these conditions on tree performance.

Weedkillers.

At the request of the A.R.C., two preliminary trials have been made to find out whether weedkillers can safely be used in orchards. These trials were carried out in old apple and pear plantations respectively. Applications of three different types of weedkiller—sodium chlorate, 2-methyl-4-chlorophenoxyacetic acid, and DNOC in a standard gas oil emulsion—were made on the ground under the trees in May, 1949. The absence of any visible effects on the trees in one season does not justify

any conclusion regarding the harmlessness of weedkillers to fruit trees, for the rainfall during the summer may not have been sufficient to bring the weedkillers in contact with the tree roots, and further trials are needed.

The use of 2-methyl-4-chlorophenoxyacetic acid is also being tested to control *Equisetum* in an established orchard.

Part of a Brompton plum rootstock layer bed, heavily infested with bindweed (*Convolvulus arvensis*) was sprayed at the rate of 250 gallons p.a. with 250 p.p.m. of the herbicide MCPA on 20th August, 1948. There was less bindweed in the treated area in 1949 and rooted layers harvested in the winter of 1948 have behaved normally. The trial will be repeated.

Pruning.

The trial of renewal versus established-spur pruning methods, applied to vigorous mature trees of Cox's Orange Pippin, has now been ended owing to the serious damage caused by collar rot in 1948. Trees under both pruning treatments were affected.

The trial, started in 1948, to test the effect on blossoming of maintaining a proportion of established spurs in a renewal pruned tree, has been maintained on young trees just forming fruit buds in quantity.

A trial comparing "pillar" pruning with established-spur pruning has been begun on trees of Cox's Orange Pippin and Worcester Pearmain on M.VII. The treatments on Worcester Pearmain are subdivided to study the effect of pinching out the terminal bud on laterals in relation to fruit-bud formation and " bare " wood.

A paper on the production of a primary branch framework on fruit trees was published (E.306).

Pruning methods are being studied on young trees of Cox's Orange Pippin, Worcester Pearmain and Laxton's Superb on M.II and M.IV in relation to biennial bearing. Open centre and delayed open centre trees are being pruned by the renewal and established-spur pruning methods. Lightly pruned or " regulated " trees, where leader tipping ceased after the third year from planting, are also included. Regulated trees have already cropped heavily for their size and with Laxton's Superb they are already showing signs of being biennial.

A " pilot " trial of four pruning treatments applied to mature trees of Morello cherry has been continued.

Growth and cropping observations are being made on certain mature apple and pear trees which have ceased to make extension growth during recent years and appear to need little or no annual pruning.

A pruning trial was started on six varieties of peach, planted at Bradbourne for study of bush peach culture. Half were winter pruned to a vertical leader and four branch leaders between 16 in. and 48 in. from the ground. The remainder were left unpruned till making good growth in May, when any branches which had died at the tips were cut back to the second strong shoot.

Fruit Thinning.

In an apple thinning trial, begun in 1945 on trees of Duchess Favourite on M.IX, trees thinned by the leaf count method, allowing one fruit to every 10, 20 or 30 leaves, are compared with unthinned trees. This year the crop was generally light and for the first time no differences in crop between thinning treatments were shown. Nevertheless, the fluctuation in crop from year to year on the unthinned trees continues.

In the fruit thinning trial on Ontario plums, despite a good crop, this year the thinning failed to increase fruit size. Drought may have been a limiting factor.

Biennial Bearing.

Successful control of biennial bearing of Miller's Seedling has been achieved by removal of about 85 per cent. of the fruit buds during the dormant season, or by removal of the same percentage of blossom clusters at pink-bud stage (E.300). So far these treatments have been applied by hand only. The " off year " defoliation treatments have so far been less effective in controlling fruit bud formation. It has been found that the defoliation has to be very severe to have any appreciable effect on the tree, and has to be carried out fairly early in the season in order to bring about the greatest reduction in leaf area. Recovery after treatment is also more rapid early in the season, before the leaves have ceased growth. Most of the defoliation has been done by hand in these experiments, but a preliminary trial of the use of chemical sprays for defoliation was made.

In 1949, a natural " on " year for the alternate bearing varieties at East Malling, the fourth successive crop was recorded from the trees of Miller's Seedling to which the control measures bud-rubbing and blossom-thinning were applied in 1946. Records will be maintained to see how long the effect of a single treatment lasts. In the case of trees treated in 1947, for which three years' records

are now available, the behaviour is not uniform. Further observations will make it possible to decide whether it will be necessary to apply further corrective treatment to individual trees in early Spring.

Records have also been maintained on the trees in the defoliation trials of 1947 and 1948. The trees of Miller's Seedling, defoliated in the "off" year 1947, have cropped lightly in 1949. In this year also some of the spray treatments applied in 1948 have reduced the crop considerably, notably a 1 per cent. solution of sodium dinitro-orthocresylate. Only by a trial and error method will it be possible to determine the concentration which will reduce the crop in the year following treatment without doing so to such an extent that the year of cropping merely changes. The defoliation trials so far conducted indicate that very severe defoliation is necessary to produce any effect on the crop in the succeeding year. The use of chemical sprays for defoliation, while advantageous from the practical point of view, introduces the complications of damage to growing tips and spurs.

Spur life history studies have been continued for a second year on the varieties Worcester Pearmain, Cox's Orange Pippin and Bramley's Seedling.

In 1949, a number of new trials were commenced. The bud-rubbing treatment, which has given such promising results in the case of alternate bearing trees of Miller's Seedling, has been applied to Bramley's Seedling to determine its effectiveness. Two different degrees of treatment—severe and light—have been tried. Bud-rubbing and blossom-thinning treatments have also been applied to the biennial variety Laxton's Superb in conjunction with defoliation, in order to determine as far as possible to what extent the success of these treatments is due to the increased leaf area resulting from them. A preliminary small-scale trial has been carried out on Miller's Seedling to determine the effect of certain chemicals as blossom-thinning agents. At this stage it is too early to assess the value of the results. It is hoped to extend this work in the coming year. (See also III D, p. 34.)

During the winter of 1948-49, some trees of the biennial varieties Miller's Seedling, Melba and Gladstone, and the regular variety Winston, were planted to provide material for future experiments.

Frost Damage Investigations.

A review of the present position of frost research (E.315) showed how frosty areas can be forecast, and what measures, based on existing knowledge, can be taken to avoid spring frosts or mitigate their severity.

Further tests and improvements of the new freezing rooms were made, and it has now proved possible to get uniform temperature conditions without violent air movement, and also uniform and controlled cooling and thawing rates, approximating to those commonly found in nature. Other matters tested, with a view to standardizing freezing conditions, have been the effect of the soil mass in the pots containing the experimental trees and various ways of insulating it ; the effects of wet and dry soil ; light and heat, before and after cooling ; and rate of cooling and thawing.

Besides helping in the important matter of getting standardized methods, these tests have also thrown further light on various factors which affect frost damage itself. Measurements of temperatures within the fruit buds and in the air, using fine wire thermocouples, have proved a valuable part of each test. Further work has been done on supercooling. The part played by the wood and the leaves has been studied.

In an attempt to get an accurate measurement of varietal resistance to frost, a number of varieties of apple, pear, raspberry and strawberry were frozen under comparable conditions. No very outstanding frost resistance was found, and the results were not always consistent. Results of measuring frost damage in the field also did not always agree with popular opinion ; and it is clear that factors other than frost damage itself may play a large part in determining the final crop.

In order to secure some material with marked differences in frost resistance, flowers of King of the Pippins were pollinated with *Malus Zumi*. Seedlings of this cross are reported by the German worker Rudorf, to segregate for frost resistance, showing sharp variations. A preliminary attempt was made to select frost resistant apple seedlings by subjecting them to —6·5° C. for four hours. Out of 625 seedlings of open pollinated Ellison's Orange, Worcester, Early Victoria and Cox, used for this purpose, twenty of the most damaged survivors and twenty of the least damaged were selected. These will be budded on to dwarfing stocks (M.IX and 3426) to hasten their flowering, and the flowers will then be tested to find if there is any correlation between the frost resistance of the growing shoots at the seedling stage and the flowers at maturity.

Some strawberry plants, reputed to have blossoms capable of withstanding —15° C., were imported from the U.S.A., by courtesy of Dr. G. M. Darrow. They are not commercial varieties, but may serve as useful breeding material.

In the plantation, air and bud temperatures were recorded with fine thermocouples on several nights when radiation frosts occurred. The incidence of dew and hoar frost were recorded, and important contrasts between conditions in the open and in the freezing room, in this respect, were noted. Data on blossom truss pose, in relation to cooling, were collected. Water sprinkling as a frost

control measure was tried on some dwarf trees at Bradbourne. The results were very encouraging, though it has yet to be shown whether the treatment would be practicable on a large scale. A report appears on p. 63. Temperature measurements over grass and cultivated parts of a cherry orchard during the blossom season were made, using improved equipment. Soil temperatures were also recorded.

Intensive Fruit Culture.

In the main walled garden at Bradbourne and in the demonstration gardens, crops were considerably heavier than in 1948. The largest demonstration garden (described in *Annual Report* for 1943, p. 96), yielded a total of 6½ cwt. of fruit of all kinds. Some of the dwarf pyramids provided good material for experiments with water-sprays as an anti-frost measure (see above).

Varieties and Classification.

It is planned to reduce the variety collections, as those at the National Fruit Trials Station at Mereworth become available ; but meanwhile they are being maintained.

The gage and plum variety collection is now twelve years from the bud. Jefferson's, Denniston's Superb and Warwickshire Drooper carried approximately 135 lb. per tree ; Ontario 98 lb. ; Golden Transparent, Victoria and Late Orange 90 lb., and Early Transparent 80 lb. per tree. There was little fruit splitting or brown rot, except on the late varieties Reine Claude de Bavay and Coe's Golden Drop.

In the apricot collection the varieties Early Moorpark, Old Cape and Croughton carried good crops of fruit. Grosse Pêche, Moorpark and Bulida had fair crops, Moorpark ripening more than a week earlier than the so-called Early Moorpark. A trial of six peach varieties on Brompton rootstock, for studying methods of culture as bushes, using two pruning treatments, was planted at Bradbourne.

Breeding.

Enlarged greenhouse facilities have made possible an extension of the breeding work with apples. The production of new late flowering and frost avoiding varieties of high quality was the main objective of crossings made during 1949. Varieties used as parents included Jonathan, Cox's Orange, Crawley Beauty, Edward VII and Médaille d'Or. The seeds obtained are being shared with the Horticultural Research Station at Wageningen, Holland, which provided assistance in the work. Several promising new Woolly Aphid resistant apples, raised at East Malling, were also recrossed to improve their fruit quality.

Good crops have been harvested from an area of mature trees frameworked with new varieties produced at East Malling. Tydeman's Late Orange, a seedling from a cross between Laxton's Superb and Cox's Orange Pippin, is being distributed for general cultivation during 1949-50. The fruit is of high quality and matures at the end of February. Storage tests at the Ditton Laboratory have so far proved satisfactory ; they are being continued. In addition, several new kinds likely to prove of commercial value are being kept under close observation.

Some very promising early dessert apples and several Woolly Aphid resistant kinds with fruits of good appearance and flavour were among about seventy seedlings selected for further trial. A number of new pears which appear to combine high fruit quality with heavy cropping and other useful commercial characteristics have also been selected for trial.

The search for methods of still further shortening the " juvenile period " in apple and pear seedlings is being continued. The effect of the new very dwarfing apple rootstocks, bred at East Malling, in hastening fruiting is being studied, as are cultural treatments such as summer pruning, ringing and bending. The overgrafting of seedlings in the " juvenile phase " with wood from mature trees and the grafting of young seedlings onto rootstocks at the cotyledon stage are being tried.

Little further progress can yet be reported in the breeding of quinces suitable for pear rootstocks. A preliminary survey of the Angers, Fontenay and Provence quinces collected from Continental nurseries as well as of the reputedly cold resistant varieties from Pillnitz has been made. Although the varieties within each group resembled one another in general appearance there were many small points of difference between them which indicated a seedling origin. It was concluded that such general names as Angers, Fontenay and Provence were used originally in a geographical sense and that, within these larger groups, numerous varieties have been selected and cultivated. Attempts to raise hybrids between the quince and pear have not so far been successful and crosses between quinces and the quince pear hybrid *Pyronia veitchii luxemburgiana* also failed, although seedless fruits were obtained.

Growing interest in the culture of peaches out of doors has made the provision of more suitable varieties a matter of importance and material is now being collected for small-scale selection experiments with this object.

B.—Small Fruits.

Varieties and Classification.

Strawberries.—Severe drought in early summer resulted in poor yields on all plots. The fourth crop from the five-year-old trial of Huxley and Perle de Prague was at the rate of approximately two tons per acre of the former and five tons per acre of the latter. About 15 per cent. of the Huxley and 30 per cent. of Perle de Prague was first-grade fruit. In the four-year-old variety trial, Tardive de Léopold cropped most heavily at about five tons per acre, with Lefebvre, Oberschlesien and Huxley giving 2½-3½ tons. Three-year-old Tardive gave nearly 4 tons per acre, Sovereign 3, Perle de Prague 3½ and Lefebvre less than 2 tons per acre. Severe virus disease symptoms became visible on all these plots in October.

Auchincruive Climax, planted in 1947-48 and deblossomed in 1948, cropped at the same rate as undeblossomed plants giving 1·6 tons-acre. Huxley and Perle de Prague on the same plot gave 1·3 and 1·9 tons per acre respectively and Madame Lefebvre only 1 ton. On all plots Perle de Prague was notable for its comparatively heavy crop and very long season.

New trials of stocks of tolerant and sensitive varieties gave small crops in their maiden year. Severe virus infection of the sensitive varieties became apparent late in the year and this trial has been discarded.

Following the discovery of a variant form of Royal Sovereign in a grower's nursery, a survey was made of sister stocks at the Research Station and elsewhere. No variants were found amongst the plants which came from the insect-proof " gauze-house " in 1948. Those derived from 1947 gauze-house stock included 8·5 per cent. of variants and also a few plants possessing both types of petiole hairs. Further research established that the variant must have arisen as a bud sport, forming a sectorial or mericlinal chimera. Stocks have been maintained for research purposes, and the variant has been eliminated from propagation beds. A report (E.319) describing the chimera has been published (see also p. 61).

Raspberries.—The nine varieties in the oldest cropping trial, which in 1949 yielded its eighth crop, gave a result somewhat different from that of previous years. For the first time, Malling Landmark failed to take the first place, coming third, behind " G " and Malling Jewel* (J) ; Malling Enterprise, having partly recovered from severe injury due to cane-blight, came fourth ; and " H ", which has usually occupied second place, fell back to seventh, probably owing to rather pronounced loss of vigour. The rear was brought up by Norfolk Giant and Baumforth B, both with less than one ton per acre ; even the heaviest crop, that of " G ", was under 2½ tons per acre.

Since this plot has now yielded as much information as can be expected from it, it will not be retained any longer. Owing to the unequal incidence of cane-blight, the 8 years' cropping figures are somewhat misleading ; it is not proposed to publish them.

The third crop of the trial planted in 1945-46 was considerably heavier than that of the older trial, reaching a maximum of about 4½ tons per acre. The order of cropping may have been slightly altered by the exceptional drought ; Malling Promise appeared to be more affected than any other variety, and occupied fourth place, being exceeded by Malling Exploit* (X), " Y " and " W ", in that order. Of the other 8 varieties in the trial, Newburgh came sixth and Norfolk Giant tenth.

In the youngest trial, which yielded its first crop, Malling Promise did relatively better, taking second place. The lead was taken by a hitherto untested seedling, 51/47, with nearly 1½ tons per acre. Past experience shows that the first season's cropping order may be considerably altered in later years ; though 51/47 produced a good berry, and may be even earlier than Malling Promise, no opinion can yet be expressed on its cropping powers. (See also p. 51, Scottish Investigation.)

Black Currants.—The yields in the black currant variety trial were moderate. Triple X remained the best cropper, with just under 2 tons per acre, and Westwick Choice came next. Boskoop cropped badly for the second successive year.

Red Currants.—Although the red currants in the variety collection have maintained differences in vigour and cropping, a considerable number of losses have reduced the value of this trial, which will not be continued.

Propagation.

Strawberries.—A ¼ acre runner bed of Auchincruive Climax M.46 was raised and, in spite of slow growth during the dry summer, produced a good yield of healthy plants. Only small runner beds of other varieties were raised, and, as some virus and Verticillium Wilt appeared in these, none of these plants were distributed.

* For description of these newly named varieties see p. 75.

A number of small consignments of nuclear plants raised in the insect-proof gauze-house were distributed to various centres at home and abroad.

The unusually favourable conditions for virus spread upset the arrangements made for the distribution of a re-selected Royal Sovereign clone, M.47. In the isolated nurseries on the North Downs some 2.5 per cent. of yellow-edge infection occurred, late in the season ; and it was, therefore, decided to withhold any new issue until another stock can be worked up.

These recurring difficulties stress the need for a Nuclear Stock centre well away from the main fruit growing areas.

Breeding.

Raspberries.—Of the twelve families germinated in 1945, 112 more selections were propagated during the year. Most of the 135 selections previously propagated came from three of these families ; almost all of the new selections have come from the other nine, which were slower in making a good start, and could not be fully observed until 1948. Notes made in 1949 have indicated some 45 more seedlings, not yet propagated, some or all of which might be worth selection.

A few plants of the four families germinated in 1948 have produced their first fruit ; it seems likely that these families will yield some improved forms of the " purple-cane " hybrids (*Rubus idaeus* × *R. occidentalis*). In addition it is hoped to obtain forms of *R. occidentalis* with good fruit, and more resistant to Verticillium Wilt than are any of the American varieties so far tested at East Malling.

Seeds of one cross (a repetition of Family 51, which produced Malling Promise), and of six self pollinations, have been sown. Some seed of this cross was sent to the Department of Scientific and Industrial Research in New Zealand, and to the Department of Horticulture at Melbourne, Victoria, to form the basis of raspberry breeding experiments there.

Seeds of several American varieties, named and unnamed, and of a cross between two of them, were very kindly sent by Mr. G. R. Slate, of the New York State Experiment Station, Geneva, N.Y. It is hoped that these will form a basis for producing commercial varieties with brighter coloured fruit than those now available in Great Britain.

Black Currants.—The new variety Amos Black, which has the valuable characteristic of very late ripening, will be distributed in the autumn of 1949. Three other new varieties of promise are now being tested in the National Fruit Trials. Seedlings of both black and red currants raised from seed collected in North Sweden and Finland are being studied with a view to their possible use in transmitting greater hardiness to future varieties. Hybrids between the black currant and other *Ribes* are being kept under observation and attempts are being made to produce fertile forms by the production of tetraploids. Tetraploid black currants raised from seed obtained in Finland are being studied. The use of colchicine as an agent for the production of polyploidy in *Ribes* is also under examination.

Strawberries.—No new families of strawberry seedlings were raised during the year and a considerable reduction in the area devoted to breeding work with this fruit has been possible. A plantation of about 1,000 seedlings from Huxley Giant yielded extremely disappointing results and has been discarded. The only recent planting was of about 300 seedlings from crosses between Royal Sovereign, Sir Joseph Paxton, Deutsch Evern and Huxley Giant. Trials are being continued of a number of selected seedlings which have shown promise, but no breeding work with this fruit is contemplated at present.

Cultural Measures.

Strawberries.—A cultural trial of Huxley, comparing matted rows and matted beds with spaced rows, suffered severely from drought, considerable wilting occurring in the matted beds especially. Under these circumstances the matted bed gave the lowest and the spaced row the highest crop—the reverse of previous results with Royal Sovereign in more normal years. On the same Plot a comparison of burning the straw litter, cutting and removing the leaves and merely cleaning, after fruiting, was carried out. Temperatures within the crowns were measured with thermocouples.

Loganberries.—The manurial and training trial on loganberries has been continued. Of the various manurial treatments, cover cropping has given poor results, which may possibly be accounted for by failure to turn in the cover crop early enough to avoid competition in the spring, or by disturbance of the loganberry roots during turning in. Reference has already been made to a new trial comparing the performance of ten different autumn annual cover crops among loganberries.

Early in 1949 it was suggested that certain cane symptoms might have been due to contact with rusty wire. A small trial was started to investigate this point, but no differences appeared in 1949 between cane on rusty wire and on clean wire.

Black Currants.—The 1949 crop of the manurial trials on black currants was again poor, perhaps owing to dry soil conditions or to the exposed position. There was much running off. A severe attack of the greenhouse red spider followed the application of DDT to control midge. In the manurial trial involving the use of sewage sludge and derived composts in comparison with inorganic fertilizers, leaf samples were again taken for determination of nitrogen content at Long Ashton. The straw/sludge compost, previously supplied by workers at Rothamsted, is now made here. In the other trial, the biennial applications of straw, farmyard manure and meat and bone meal are again being made in the autumn and winter 1949-50.

The pruning trial designed to show any effect on crop caused by pruning bushes of Triple X immediately after fruiting compared with normal winter pruning has cropped again this year. In spite of double the crop recorded last year, there was no appreciable difference, either between the two pruning treatments, or the winter or summer nitrogen treatments for which the plots are sub-divided.

Irrigation.

An irrigation trial was carried out on Huxley strawberries. The equivalent of one inch of rain was applied at the beginning of the cropping period. These plots yielded nearly twice the crop of the unwatered plots. This is not surprising, as many plants wilted on the latter. Huxley appears more sensitive to drought than some other varieties.

Frost.

Various small fruits are included in the freezing room tests (see p. 25). A trial of time of strawing strawberries, in relation to frost damage, was repeated ; but no important frost occurred during the trial.

C.—Nuts.

Low temperatures on 8th and 10th May, when the screen temperature went down to 29° F., damaged the pistillate walnut flowers, or the young buds where the flowers were developing. All the trees were affected except those on Newgates field, on higher ground, which were the only trees to carry a good crop this year. The quality of the nuts was very good ; all were fully matured and well sealed. All the trees grew well, and showed no sign of any bad effect of the drought.

D.—Horticultural Meteorology.

The routine meteorological observations and special records of air temperature and soil moisture in relation to various experiments were maintained. During the year the Meteorological Plot and records were inspected by officers of the Meteorological Office and rated as very good. Screen and grass temperatures are now regularly recorded in the Bradbourne Gardens, as well as on the Meteorological Plot. Cup counter anemometers are erected at the Research Station and at two of the rootstock plots on contrasting Kent soil types, at different heights above sea level.

The establishment of a Crop Weather Station on a fruit farm in Kent on the 500 ft. contour as a sub-station from East Malling is under consideration and it is hoped that this will materialize during 1950. A comparative study of climatic data from East Malling and the " hill " fruit lands will be extremely valuable for research and advisory work.

Assistance has again been received from the Meteorological Office, Forecasting Department, who sent us frost warnings which have enabled precautions to be taken for safeguarding special plants from damage.

Publications during the year.

In Relation to Tree Fruits.

Glenn, E. M. **Walnuts for amateurs.** Amateur Gardening, 1949, No. 3378, 16 (E293).
Garner, R. J. **Plum rootstocks.** Worcs. agric. Chron., 1948, **17**, 53-71 (E294).
Glenn, E. M. **Interested in walnuts ? Cultural difficulties explained.** Fruitgrower, 1949, **107**, 287-8 (E298).
——— **More about walnuts. II. Varieties and propagation.** Fruitgrower, 1949, **107**, 387-8 (E299).
Singh, L. B. **Studies in biennial bearing. IV. Bud rubbing, blossom thinning and defoliation as possible control measures.** J. hort. Sci., 1948, **24**, 159-77 (E300).

ROGERS, W. S., RAPTOPOULOS, TH., and GREENHAM, D. W. P. **Cover crops for fruit plantations. IV. Long term leys and permanent swards.** J. hort. Sci., 1948, **24**, 228-70 (E301).

———, ———, ——— **Cover crops for fruit plantations. V. Effect of form and time of application of nitrogen on orchard swards.** J. hort. Sci., 1948, **24**, 271-83 (E302).

PRESTON, A. P. **The production of a primary branch framework on apple trees.** Rep. E. Malling Res. Sta. for 1948 (1949), 55-63 (E306).

——— **An observation on apple blossom morphology in relation to visits from honeybees (*Apis mellifera*).** Rep. E. Malling Res. Sta. for 1948 (1949), 64-7 (E307).

TYDEMAN, H. M. **Trials with new quince rootstocks.** Rep. E. Malling Res. Sta. for 1948 (1949), 68-74 (E308).

——— **A new apple variety: Tydeman's Late Orange.** Rep. E. Malling Res. Sta. for 1948 (1949), 75-6 (E309).

GARNER, R. J., and HATCHER, E. S. J. **Utilization of an ornamental lake for water-table control experiments in relation to vegetative propagation.** Rep. E. Malling Res. Sta. for 1948 (1949) 77-80 (E310).

GRUBB, N. H. **A seasonal influence on cherry pollination and ripening.** Rep. E. Malling Res. Sta. for 1948 (1949), 131 (E314).

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GARNER, R. J. **Rootstock propagation and fruit-tree raising.** Rep. E. Malling Res. Sta. for 1948 (1949), 132-5. Grower, 1949, **31**, 453-7 (Under slightly different title) (E316).

——— **Some aspects of propagation research, with special reference to fruit trees.** Mededelingen Dir. Tuinbouw, 1949, **12**, 390-3 (E318).

In Relation to Small Fruits.

GRUBB, N. H. **Lightning damage to raspberries.** Rep. E. Malling Res. Sta. for 1948 (1949), 81 (E311).

TYDEMAN, H. M. **Amos Black: a promising new black currant variety.** Rep. E. Malling Res. Sta. for 1948 (1949), 82 (E312).

ROGERS, W. S. **A bud-sport in Royal Sovereign.** Grower, 1949, **32**, 413-4. Fruitgrower, 1949, **108**, 403 (E319).

——— and WILSON, D. J. **L'Amélioration du fraisier en Grande-Bretagne.** Le Bulletin Horticole, 1949, **4**, 279-82 (E321).

(See also III (F55).)

Meteorology.

PRESTON, A. P. **Weather conditions during 1948.** Rep. E. Malling Res. Sta. for 1948 (1949), 83-5. (E325).

II. STATISTICS AND RECORDS

By T. N. HOBLYN and S. C. PEARCE

The activities of the Statistics Section may be divided into two very broad classes : (*a*) routine advice and assistance in the design, methods of recording, summary and statistical analysis of experiments conducted by all Sections, and (*b*) special investigations for the improvement of methods in connection with all the above duties.

The routine work, which incidentally includes the filing and summary of records on many field trials, calls for no special comment, except in the field of statistical analyses. These have, of course, increased in number as the Station has grown ; however, with improved techniques, certain analyses, formerly regarded as unusual or specialized, are now carried out for many experiments regularly. As an example, the analysis of covariance, notably in connection with corrections for missing trees or plots, may be cited.

Surveying on the experimental farm and the production of maps for general use may be mentioned as one of the more unusual duties of a Statistics Section.

Developments in experimental design and technique have been a constant study for many years. Usually as the basis, measurements obtained in the ordinary course of experiments designed for other purposes have been used (see below), though, sometimes, notably in connection with sampling studies, special records in existing plantations have been possible. Now, for the first time, a uniformity trial of apples, specially designed to answer specific questions on variability and on the relationship between the various measures of vigour and cropping of the tree at different ages, is being prepared.

Experimental Design.

Experiments on trees now being designed are mainly of two kinds, in which (1) the treatments start at once, and (2) the treatments do not start until the trees are established, after a period of " calibration " during which individual tree records are made. (See also p. 83.) In either, flexibility of design so that the trees can be used for a long period of time, one set of experimental treatments perhaps succeeding another, is most important and new methods for attaining it are continually being evolved. Methods of changing treatments, notably on trees originally arranged in randomized blocks for one special experiment, have recently been summarized ; and since, a similar method, where the original design was a Latin square, has also been worked out. In the course of this investigation methods of design and analysis, particularly relating to the use of outside guard rows, have come to light which will be useful in planning new layouts.

The evolution of valid restrictions upon randomization has been taken further and appropriate analyses of variance can now be carried out without the complications previously involved. Such restrictions are useful for trials, e.g. of raspberries, where certain varieties cannot be grown side by side, or where the trees in the plantation may need to be thinned out at some future date.

Variation Studies.

The variability in cropping over long periods of four sets of apple trees has been examined (M7). It was shown that coefficients of variability decrease both as the trees grow older and as the length of the experimental period is increased. Trees tend to settle down in variability after about ten years from budding. The method of covariance can usefully be employed to reduce crop variability using the trunk girth at the beginning of the experimental period, though not if the treatments are applied right from the time of planting ; no useful means of correcting the yields in such experiments have yet been found.

Examining the variation in the logarithm of the trunk girth at different periods in the life of apple trees, it appears that the variability is largely made up of permanent or semi-permanent sources of variation ; but, provided they are healthy and undamaged, differences in size of tree in the nursery do not persist very long, especially if the trees are planted as one-year-olds. This investigation has made it possible to recommend with some confidence the age at which experimental treatments on established trees should start.

In strawberries, the variation in past trials has been re-examined. Despite attempts to reduce it by cultural means, crop variability remains high ; but measurements of vigour may prove useful for the correction by covariance of future crops, though they are of little value for crop forecasting.

Collaboration with research workers in West Africa and the Argentine has afforded opportunities for the examination of the results of uniformity trials on cacao and vines respectively. In the interpretation of these trials, particular attention has been paid to the economical use of land.

Studies of sampling methods for size of fruit in cherries, frost damage to buds, flowers and fruits of various fruit plants and " running off " of black currants are in progress.

Publication during the year.

Pearce, S. C. **The variability of apple trees. I. The extent of crop variation and its minimization by statistical means.** J. hort. Sci., 1949, 25, 3-9 (M7).

III. PLANT PHYSIOLOGY*

By M. C. VYVYAN

A.—Vegetative Propagation (see also I. A).

The routine experiments with hardwood stem cuttings of rootstocks have been transferred this year from lake soil to loam, on account of the construction of the experimental island. The standard dip method of growth substance treatment—5 mg. β-indolyl-butyric acid per 10 c.c. 50 per cent. alcohol—has been used systematically. Experiments with source plants grown under controlled nutritional conditions in sand culture have been continued. They have indicated that both the level of total nutrition and the relative levels of nitrogen and potassium supply may influence the growth of the plants themselves, the rooting capacity of hardwood and softwood cuttings taken from them, and the response of these to treatments with growth substances and to the supply of nitrates after planting.

The course of growth of stems, leaves and roots of cuttings of Myrobalan B, grown on two soils, has been followed for a second season. Recommendations have been made on which the N.A.A.S. (S.E. Province) has initiated a series of hardwood cutting trials with gooseberries ; experimental plans and growth substance solutions are being supplied by the Research Station.

Arrangements have been made for collaboration with the Nursery Research Station, Boskoop, Holland, on problems connected with the propagation of fruit trees by stem and root cuttings.

B.—Physiology of Growth and Form in Fruit Trees.

The investigation into the physiological basis of the reciprocal influence of scion and rootstock on the growth and form of the composite tree, which was discontinued in 1940 on account of the war, has been resumed. Past results are being examined with a view to publication, and new experiments, based on these results, have been planned.

The physiological basis of tree response to stem pruning is also being examined. An investigation into the relationship between shoot extension growth and the thickening of the trunk and the branches of trees under different pruning treatments is in progress in collaboration with the Pomology Section.

An investigation into the influence of the leaves, and the effects of the addition of sugar and growth substances upon shoot growth, internode length and thickening, has also been begun, and the possibility of using growth substances to control the crotch angles in plum trees is being explored.

C.—Abscission, and the Shedding of Fruits, Blossoms and Leaves.

A further trial has been carried out on the control of " June drop " in Cox's Orange Pippin by growth substances, to determine the best date for application. The growth substance was applied, either alone or mixed with a routine protective spray, on four different dates, and on all four dates. The dates were : early May, 1st June, mid-June and mid-July. There is some indication that the early sprays reduced the " June drop ", but the full results will not be known until the fruits have been picked and counted. A somewhat similar trial has been carried out with Bramley's Seedling.

Experiments on the same two varieties have been carried out, in collaboration with the Staff of the Ditton Laboratory, to determine the after-effect of growth substance sprays and of a postponement of the date of picking, upon the quality attained by fruits in cold store (F54).

Various exploratory experiments have been made with a view to opening up new lines of investigation. Work in past years has indicated that the application of α-naphthalene-acetic acid (NAA), by various methods, to pedicels from which the fruits or blossoms have been cut off, may prevent the abscission at any stage from blossom-bud to mature fruit ; this year an attempt has been made to find out if a spray of NAA, applied to a whole tree of Cox or Worcester Pearmain, will control the various waves of natural shedding that normally occur. In another small scale trial, sprays of NAA, nitrogen (as urea), and potassium (as potassium sulphate) were applied to Cox, either alone or in combination, six times between early June and September. Preliminary examination of the results suggests that potassium provided an even better control of drop than NAA, and for a longer period. This will be

* Members of Staff of Research Institute of Plant Physiology, Imperial College of Science are working in collaboration with this Section.

tested by a full-scale trial in 1950. Small-scale trials have also been carried out with four different growth substances on five apple varieties ; these were inconclusive, but will be repeated.

Continuing intensive experiments on the abscission process, a further attempt has been made to find out if it is the *concentration* of the applied NAA or its *amount* that determines how long abscission is postponed. The results are not yet fully conclusive and further work is required. Another experiment was aimed at determining the effect of the length of tissue through which the NAA must pass, upon the inhibition of abscission. This year the work was done on leaf petioles and the results suggest that here it is the longest path that is best, not the shortest as found for fruit pedicels in previous years. This apparent contrast requires further study.

D.—Blossom Thinning by Sprays.

Preliminary experiments have been carried out, in collaboration with Pomology (see I. p. 25). Sprays of NAA, DNC, and of tar oil were applied at certain selected stages in the development of the blossom truss. Results suggest that an NAA spray might be useful, but that correct timing would be difficult. Sprays of DNC were more effective, but tended to damage the foliage.

E.—Hormone Relations in Fruit Trees.

Auxin studies of current year shoots of apple and plum rootstock varieties have been extended. During the winter, an ether extraction method was used, by which non-transportable auxin (i.e. auxin not observable by the direct agar-collecting method) was found in the dormant stem tissues. There was a marked contrast between Myrobalan B plum and Crab C apple, the former yielding auxin throughout the dormant period from the greater part of the shoot, and the latter only up to early December, this being limited to the basal region. Observations have been commenced on the auxin relations of cuttings. The presence of an inhibiting substance, suspected during earlier experiments on transportable auxin in the growing shoot, has been confirmed by the ether extraction method, and attempts are being made to carry out auxin-inhibitor analysis with the Avena coleoptile. Inhibitor has been extracted from apple leaves and its relation to auxin will be investigated.

A further series of auxin transport experiments has been conducted, using isolated stem sections of varying length, with storage periods ranging from two to twenty-four hours. These have demonstrated auxin accumulation at the extreme base of the section, and also a fairly rapid disappearance of the active substance once it has reached the base.

Investigation into Avena coleoptile technique has been continued. The chambers have been in continuous use and larger-scale tests have led to a detailed examination, still in progress, of the response of coleoptiles to standard indole-3-acetic acid solutions. The relation between the variability of the oat grains and conditions prevailing at harvest is being investigated. The 1948 crop was universally unsatisfactory, and further supplies of 1947 grain had to be obtained. It is hoped that the 1949 grain will have a high germination capacity.

F.—Fruit-Splitting in Cherries and Plums.

Experiments on the control of splitting in cherries were foiled by lack of conditions that cause the trouble, and the artificial treatments aimed at inducing splitting were mistimed. Useful information was gained, however, as to the best types of spreader to use and on methods for estimating the amount of damage.

Field experiments with plums were likewise unsuccessful, partly because the spreader used proved ineffective, but mainly because the effect of different rootstocks was so pronounced that it masked all others. Laboratory experiments with plums gave good results. Splitting induced by immersing the fruits in distilled water for 1, 2 or 4 hours, was reduced to about one half when the fruits were first treated with calcium hydroxide solutions at concentrations of 250, or even 125 parts per million.

G.—Spray Damage.

A preliminary trial has been carried out of the control of spray damage to Cox foliage by parathion. This substance, with and without lime-sulphur and NAA, was sprayed on to Cox branches in June and counts were made of the leaves which showed the typical colour pattern of " darker green veins on a yellow background " produced by parathion on Cox, and subsequently of dropped leaves. The drop of leaves due to parathion was increased by lime-sulphur and reduced by NAA.

PUBLICATIONS DURING THE YEAR.

VYVYAN, M. C., WEST, C., and BARLOW, H. W. B. **Use of sprays to control fruit drop. V. Effect of a naphthalene-acetic acid (NAA) spray, and of a delay in picking, on the rate of dropping and the storage behaviour of fruits of Cox's Orange Pippin.** Rep. E. Malling Res. Sta. for 1948 (1949), 86-91 (F54).

HATCHER, E. S. J., and GARNER, R. J. **Aspects of rootstock propagation. I. The influence of occasion of planting on the establishment and growth of Myrobalan B plum hardwood cuttings.** Rep. E. Malling Res. Sta. for 1948 (1949), 92-8 (F55).

RAWES, M. R., and HATCHER, E. S. J. **A method of estimating hormone activity in the plant.** Rep. E. Malling Res. Sta. for 1948 (1949), 157-8 (F56).

(See also I. (E310).)

IV. BIOCHEMISTRY

By W. A. ROACH

During 1948-49 the Biochemistry Section has continued the investigation of mineral nutrition and has reopened the work on the organic constituents of fruit-producing plants that was stopped temporarily early in the war.

Mineral Nutrition.

The main aim of this investigation continues to be to study the effect of the mineral content of plants on their horticultural performance so that, by improving mineral nutrition, optimum performance may be obtained. Spectacular results have been obtained in the past by diagnosing and curing plants affected by extremely severe deficiencies ; but these largely cease to be subjects for research and are now dealt with by the advisory officer. Attention is therefore being turned increasingly to the less severe deficiencies, which in the aggregate may well be of greater importance than the severe ones.

Relatively crude methods are sufficient to change a negligible crop into one of half the ideal size and to establish the fact that this has been done because the change is obvious ; but it is far more difficult to change a crop of half, into one of three-quarters the ideal size, and still more difficult to change the three-quarter crop into one of ideal size and quality and to prove that this has been done. This is particularly true for complex long-lived plants like fruit trees. To be able to deal with these less severe deficiencies, improvements both in methods of diagnosis and in methods of estimating yield and quality are necessary. Again, refinements in method are also necessary for the study of the role of mineral nutrition in, for example, the rootstock-scion effect, biennial bearing, the effect of cover crops on the trees and in certain host-parasite relationships. The importance of these problems justifies, indeed necessitates, the attempt to overcome the experimental difficulties ; and the past year has, therefore, been devoted largely to the improvement of methods of diagnosis and (to a less extent) of cure. It will be convenient to report briefly the progress made in the various methods of diagnosis and finally to mention some of the preliminary experiments and observations made that have a bearing on the effect of mineral nutrition on performance.

Analytical Methods for Elements in Plants.

The determination of traces of heavy metals such as iron, manganese, copper, zinc etc. in the presence of relatively large amounts of phosphorus, silicon and magnesium, which form precipitates that tend to take down the trace elements with them, is one of the most difficult problems of analytical chemistry. It is rendered still more difficult by the desirability of using only small samples for analysis. Frequently only small samples are available ; but, even with large samples, gathering and cleaning them are time-consuming operations ; and when, as often happens, they are heavily contaminated by soil or quarry dust, etc. it is practically impossible to make sure that each leaf of a large sample is cleaned properly : but this is relatively easy for small samples. For this purpose a small machine has been constructed. It consists of rotating buffing wheels between which the leaves are held one at a time. Progress in evolving the methods must, therefore, be judged in respect not only to their reliability and accuracy, but also the minimum percentages that they will detect and estimate of the various trace elements and the smallness of the sample necessary for the analysis.

Chemical.

The methods previously reported on have been in use throughout the year for the analysis of routine samples. This experience has shown that some of the methods still need modification. Though, on the whole, useful results have been obtained for nitrogen, phosphorus, potassium, calcium, magnesium, iron and manganese on 200 mg. samples, the accuracy has not been adequate for some of the work attempted during the year, e.g. the rapid micro methods used for nitrogen, potassium and magnesium. The hydrogen peroxide method for nitrogen was discarded and the Conway micro-diffusion one substituted, and this in turn was replaced by the micro-Kjeldahl method, using mercuric sulphate (which has been found more reliable than selenium) as catalyst. The nephelometric method for potassium has not come up to expectations and has been replaced by a colorimetric one based on the cobalt content of the precipitated silver potassium cobaltinitrite complex. The micro-nephelometer developed for this

estimation will still be of value, e.g. in estimating chloride and sulphate in plant material and a description of it is being published. The titan yellow method for magnesium has not been entirely satisfactory and alternative methods are still under investigation. The methods for phosphorus, calcium and manganese have been giving satisfactory results. Methods for iron are still unreliable and the full reason is still obscure. The silicon and phosphorus present in plant material give trouble due to absorption of the iron or to complex formation. Adventitious contamination is also serious and must be scrupulously guarded against. Progress reports on the above methods will be published in the *East Malling Annual Report* as an easy means of comparing notes with workers on similar problems elsewhere.

A method for the estimation of zinc based on extractive titration with dithizone is at present under test. This requires a sample of 1 gm., whereas only 0·2 gm. has been required for all the other analyses. It is rather tedious for routine work, and, as we are forced to use a larger sample, there is good hope of developing a satisfactory polarographic method.

The estimation of boron continues to give trouble, as it does to numerous workers elsewhere. Waxoline Purple AS has proved to be a satisfactory reagent for the estimation of boric acid, being superior to turmeric and very much better than quinalizarin. The ashing must be done carefully to avoid loss. It has proved essential to separate the boron from the other constituents in the ash by distillation with methyl alcohol. Silica apparatus has to be used throughout to avoid the boron contained in glassware and every reagent has to be purified from boron. This in itself has been quite an interesting problem. Recent figures for blanks have been reduced greatly and they are now consistent, but it is hoped to reduce them still further. A separate sample of 0·1 gm. is likely to be necessary for boron.

The early use of these methods for routine purposes has yielded results of use for both research and practical purposes and has given valuable analytical experience as to their reliability when applied to different types of samples.

The Effect of Various Sampling Factors on Analytical Results.—A start has been made on the examination of sampling methods, e.g. the effects of (*a*) the personal factor; (*b*) the inherent variability of the leaf material; (*c*) the time of day when sample was taken; (*f*) the position on the tree from which samples were taken. The results are not yet complete.

Spectrographic.

The main advantages of spectrographic methods are their sensitivity, their rapidity and the number of elements that can be determined more or less simultaneously. Their chief drawback is the fact that the presence of certain elements (e.g. phosphorus) interferes seriously with the determination of others (e.g. calcium) and the lines of one element may overshadow those of other elements.

Flame Method.—An improved modification of the Roach method has been standardized and is now in routine use. The standard sample is 15 mg. of dried plant powder. The sensitivity has been increased for elements determined by the Roach method and copper has been added to the list. This element may be determined on a 15 mg. sample, even from a severely deficient plant. The method is capable of further improvement, but this will be deferred until an arc method is in routine use. In its present form it approaches much more nearly to our exacting requirements than any other flame method.

Arc Method.—An entirely new arc method has been evolved. In this a pellet of plant powder or ash is introduced through a hollow electrode into an already struck carbon arc. This promises to be as big an advance on existing arc methods, from our point of view, as the last method is on existing flame methods.

Mass Spectrometer Method.

Arrangements have been made for co-operation with the Physics Laboratory of Messrs. Metropolitan Vickers, Ltd., as soon as an instrument is ready. As far as can be judged at this stage, this method has great possibilities for the mineral analysis of plants, particularly for our very special purposes.

Fractionation of Nutrient Elements.

As stated in previous years, the aims of this line of work are to separate the fractions of the elements that are present in forms useless to the plant from those that are of value to it, and to separate the latter according to their state of chemical combination, and (it may be hoped) according to their functions in the plant. The possibility of separating by this means elements that interfere with each other in spectrochemical analysis is also being investigated. The rate of progress is conditioned by that of methods of analysis, particularly the arc spectrochemical method. Work done recently should make more rapid progress possible in the near future.

Plant Injection.

Improvements in the interveinal method of injection make it relatively easy of manipulation and, in consequence, it has been used as a routine method.

Curative Methods.

Reasonably efficient methods are in practical use for the cure of all mineral deficiencies known in this country except that of iron. The injection of iron into trees is effective but causes mechanical damage that should be avoided if possible. Spraying, though effective and safe on agricultural crops, tends to cause too much damage for use on fruit trees and plants and, for unknown reasons, sometimes produces a response but sometimes does not do so. Before trying to improve this unsatisfactory position, a tour was made of French Research Stations, since lime-induced iron chlorosis is very widespread and serious in France and it was known that the problem had received much attention there. Though some useful information was collected, it was clear that no really satisfactory method of control of iron deficiency, other than solid injection, had yet been found. It will, therefore, be necessary to develop the work on this problem more vigorously.

Effects of Soil, Manuring, Cultivation and Rootstock on the Mineral Status of Fruit Trees.

Striking examples have been observed of different species, and one of different varieties of the same species, being apparently affected by different deficiencies. Thus, on the Bradbourne lakebed island, wheat, oats, barley and potato were proved by spraying to be seriously affected by manganese deficiency and these and *Chenopodium* responded to diagnostic manganese (but not iron) injections, whereas, willow, quince and Crab C apple rootstocks responded to diagnostic iron (but not manganese) injections. Tomatoes responded in different plants and at different times to iron and manganese.

In the Bradbourne gardens, Durondeau pears, Rev. Wilks and Lane's Prince Albert apples responded to diagnostic injections of iron and showed the symptoms characteristic of this deficiency ; whereas Edward VII apple, growing next to the Lane's Prince Albert apple, responded definitely to diagnostic injections of manganese, but showed no characteristic symptoms. Both symptoms and the results of injection suggested that raspberries growing between the pears and the apples were affected, some plants by manganese and some by iron deficiency. One cherry tree was affected definitely by iron deficiency. Other cherry trees showed symptoms identical with those associated with manganese deficiency, but did not respond to injection. These results epitomize impressions gathered during the past few years in growers' plantations and suggest some of the complications and difficulties in the way of really practical applications of this work.

Effect of Mineral Nutrition on an Ecological Community.

Spraying and not spraying with maganese made all the difference between an almost weedless crop of wheat, oats or barley and a dense growth of weeds that smothered the cereal when only a few inches high.

Organic Constituents of Fruit Plants.

It has become increasingly evident that, in various directions, work in plant physiology and pathology is handicapped by the grave lack of information concerning the chemical composition of the plant. In this respect plant biochemistry lags nearly half a century behind animal biochemistry. This gap in our knowledge is particularly evident when the soluble constituents are under consideration. For example, the approach from the physiological side to such problems as biennial bearing, incompatibility and susceptibility to frost damage would be greatly facilitated if it were possible to study seasonal changes in composition and the effect of nutrition and environment on these changes. Again, chemical knowledge would be of great value in the study of the pathological conditions arising from damage by insects or micro-organisms and is, perhaps, essential for the understanding of certain cases of resistance to attack. Bacterial Canker of stone fruits, Scab in apple and pear and resistance to Woolly Aphid attack may be cited as examples of problems awaiting biochemical study.

Preliminary investigations carried out intermittently in the past were sufficient to show that the chemical problems involved presented such difficulty that only by making a continuous and full-scale attack could it be hoped to gain the required information. During the past year a small team of organic chemists has been built up and a systematic investigation initiated.

A general method of preliminary fractionation of aqueous or methyl alcoholic extracts of the plant material has been devised, by means of which the soluble constituents are divided into four groups, namely, an ethyl acetate solution fraction, a basic fraction, an acidic fraction and a neutral fraction

containing the soluble carbohydrates. These fractions have been further examined chromatographically on paper and on columns of cellulose or silica gel.

The plant material used for this exploratory work consisted of leaves and young stems of an apple rootstock (411), Myrobalan B and Brompton plum rootstocks, and leaves of Conference pears.

It has, of course, long been recognized that the soluble carbohydrates play a very important part in plant metabolism. It is of interest, therefore, to note that in addition to fructose, glucose and sucrose, the trisaccharide raffinose and the tetrasaccharide stachyose have been identified. The presence of these two oligosaccharides appears to have been unsuspected hitherto, although the amounts present are comparable with those of the more familiar sugars. As their molecules consist of sucrose combined with one and two molecules respectively of galactose, the absence of free galactose is noteworthy.

The above constituents were found in all the above plants, except that the leaves of Conference pears contained no raffinose or stachyose.

The green wheat plant was examined for comparison. In it were found fructose, glucose and sucrose, but in place of raffinose and stachyose four or five spots were found lying close together on the chromatographic paper, none of which corresponded to raffinose.

These and other results being obtained are obviously fundamental to more practical applications of organic chemistry which are contemplated in the near future in co-operation with other interested Sections.

Publications during the year.

Roberts, W. O. **Prevention of mineral deficiency by soaking seed in nutrient solution.** J. agric. Sci., 1948, **38**, 458-68 (K75).

Goodall, D. W. **Studies in the diagnosis of mineral deficiencies. IV. The mineral content of barley plants in relation to potassium deficiency.** Ann. appl. Biol., 1948, **35**, 605-23 (K79).

——— **Studies in diagnosis of mineral deficiencies. V. Manganese deficiency in wheat.** Ann. appl. Biol., 1949, **36**, 26-39 (K76).

——— **Studies in diagnosis of mineral deficiencies. VI. Composition of weed leaves in relation to potassium deficiency in barley.** Ann. appl. Biol., 1949, **36**, 352-63 (K78).

Bolas, B. D. **Manganese deficiency in potatoes.** Rep. E. Malling Res. Sta. for 1948 (1949), 99-100 (K77).

V. PLANT PATHOLOGY

By R. V. HARRIS

Notwithstanding major staff changes, particularly affecting the programmes on bacterial and virus diseases, substantial progress was made in each of the main lines of research, excepting the study of raspberry cane fungus diseases which was temporarily in abeyance. Work on the latter in Scotland is reported elsewhere (see p. 51).

Bacterial Canker of Stone Fruits.

Elucidation of the seasonal cycle of the pathogens *Pseudomonas mors-prunorum* and *Ps. prunicola* centred this year on the over-summering sources of infection. Two such sources, additional to leaves, were found, namely buds and gum. The exceptionally dry summer militated against the usual successive waves of leaf-spot infection, and with this in mind quantitative data were obtained in October, shortly before leaf-fall, to assess the inoculum potential of the leaf spots under these conditions. This evidence suggests that while the *majority* of the bacteria in the leaf spots are no longer viable at this time of the year, the leaf spot provides, nevertheless, a large quantity of inoculum for the initiation of cankers in the autumn. Experiments were also started to investigate the role of the leaf scar as an avenue of autumnal infection.

In trials on the direct control of the cherry disease by spraying with bactericides, the superiority of home-made Bordeaux mixture over the manufactured copper preparations tested was confirmed. As the timing schedule used reduced, but failed to eliminate, the disease, further trials were started to determine whether control could be improved under different timing.

A severe leaf spotting of apricot (*Prunus armeniaca* L.) was investigated early this year and a bacterium consistently isolated. Shortly afterwards a wholesale shoot infection became apparent and the same organism was isolated. Some of these symptoms on shoots and leaves were later reproduced by inoculations with two of these apricot isolates. The severity of the disease suggests that under suitable conditions young apricot shoots are particularly susceptible to invasion by the pathogen. Further observation suggested a possible winter phase in the older wood comparable to that in plum and cherry. Further inoculations were made to determine the relationship between the spring and winter phases. The identity of the pathogen is being determined.

Verticillium Wilts.

In addition to research on practical aspects of the problem of progressive wilt in hops (see VIII. B) a substantial approach was made to a fundamental study of the phenomenon of host resistance with a series of experiments to determine the effects of host nutrition on the reaction of host plants other than the hop, to infection. These preliminary experiments were made to study inoculation techniques and to find the most suitable dosage levels of the nutrients. The tomato was used for most of these trials, but symptom expression on this host proved distinctly unsatisfactory. Antirrhinum and Asters, also tested, may prove more satisfactory. Nitrogen supply was definitely shown to influence the severity of symptoms, and further experiments in this direction have been planned.

In July a visit was made by Dr. Keyworth with Dr. Bradfield of the Biochemistry Section to Zurich, Switzerland, to study the work of Professor Ernst Gäumann and his associates on the physiology and chemistry of the analogous wilt disease of tomato caused by *Fusarium lycopersici*. This contact promises to prove of great value to our incipient study of the physiology and chemistry of the Verticillium Wilt diseases.

Black Root Rot of Strawberry.

This year no outbreak comparable in severity to that of 1948 occurred at East Malling, or at the N.A.A.S. Experimental Station at Botley, Hants. In collaboration with Mr. W. F. Cheal, N.A.A.S., of the latter Station, an extensive mycological examination was made in June of the root systems of plants which had survived that outbreak. Roots were graded for this purpose according to the degree to which they were affected by root rot. The many organisms isolated and identified included three species of *Fusarium* and a *Hainesia* sp. closely resembling *H. lythri*, one of the pathogens associated by Berkeley and Lauder Thompson with this disease. The relative distribution of these isolates in roots

grading from virtually normal to moribund did not suggest that the former were primarily concerned with the collapse of plants. This work is being developed by a special grant from the Agricultural Research Council.

Virus Diseases of Fruit.

Tree Fruits.

Impetus was given to this side of the programme by the appointment to our staff of Mr. A. F. Posnette, who had specialized on tree viruses in the tropics, and by the visit to this country during the year of Dr. R. S. Willison, an authority on *Prunus* viruses in Canada. In the short time available, after the former had arrived, considerable developments were made. The symptoms of Apple Mosaic were shown to develop on Malling rootstocks, Nos. I, II, IV, VII, IX, XII, XVI and Crab C, so that these are unlikely to behave as symptomless carriers in stock beds. A series of experiments was launched to study the possibility that strains of this disease exist. Evidence of transmissions of some cherry and plum viruses was obtained from tests made last year, and a preliminary survey of orchards revealed a wide range of symptoms, and showed conclusively that several important virus diseases of these hosts are of wide occurrence in this country.

Small Fruits.

An account of the isolation and some properties of strawberry virus 3 was published (C248). This, the severe crinkle virus, differs from virus 2, the Yellow-edge virus, by the longer feeding period (minimum of six days) required by the aphid vector (*Pentatrichopus fragaefolii*) before it is picked up. Both these viruses persist in the vector for several days. In combination with virus 1 (mild crinkle) symptoms of the commercial severe crinkle disease are induced on Royal Sovereign, and combined with virus 2 severe Yellow-edge symptoms appear. Severe crinkle disease is thus shown to be caused by a combination of at least two viruses and to be etiologically distinct from mild crinkle, the virus of which, however, it includes. Two distinct Yellow-edge diseases are also demonstrated.

A selection of some 23 of the Cambridge Seedling varieties were tested, and from 13 of these we were not successful in recovering virus-free plants. From the remaining 10 individuals, which were of recent origin, virus-free plants were readily segregated.

Further work on the determination of the natural vectors of Loganberry Dwarf was done, and an account of the early etiological study of this disease was prepared for publication. The bulk of research on *Rubus* viruses, however, was made by the Scottish Raspberry Investigation at Dundee and is fully reported on p. 51 of the present Report.

Problems of Disease Control.

Further progress in the development of a method for "screening" new fungicides in open plantations, using artificially infected rootstocks, included initial arrangements for an extensive testing Plot exclusively designed for the purpose. Tests on plantation trees were also continued and are reported elsewhere (VII. p. 46).

The former method has also been used for determining the period of natural infection of apples with Apple Canker (*Nectria galligena*) and this year heavy infections of M.VIII rootstocks were artificially induced.

Losses in the apple crop of 1949 due to Brown Rot were exceptionally heavy, and detailed records of incidence made by us in well sprayed commercial plantations of Cox's O.P. at East Malling, and by our collaborator in the N.A.A.S. (Mr. W. S. English) at two centres in Sussex, showed that infection through weather cracks and similar skin blemishes on the fruit, and through wounds caused by birds and wasps, were mainly responsible.

The satisfactory experimental application of finely air-divided undiluted lime-sulphur to Cox's O.P. in 1947 led to further developments in 1949. These experiments, as yet uncompleted, showed that there are clearly defined *dosage* limits which, if exceeded, may cause severe damage to foliage. The primary aim is to find the optimum combination of water-dilution and dosage which will give effective and safe control of Apple Scab.

PUBLICATIONS DURING THE YEAR.

KEYWORTH, W. G. **Verticillium wilt of the hop (*Humulus lupulus*). IV. Study of a fluctuating outbreak.** J. hort. Sci., 1948, **24**, 149-56 (C239).

CADMAN, C. H. **Raspberries—research and current problems.** The Growers' Digest, 1948, **1**, 26-32 (C242).

KEYWORTH, W. G., HITCHCOCK, M. M., and WILSON, D. J. **Experiments on the layering of hops. I. The establishment of a permanent layer bed.** J. hort Sci., 1948, **24**, 200-5 (C243).

———, and WILSON, D. J. **Experiments on the layering of hops. II. Layering young plants.** J. hort Sci., 1948, **24**, 206-13 (C244).

———, and HEWITT, E. J. **Verticillium wilt of the hop (*Humulus lupulus*). V. The influence of nutrition on the reaction of the hop plant to infection with *Verticillium albo-atrum*.** J. hort Sci., 1948, **24**, 219-27 (C245).

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VI. ENTOMOLOGY

By A. M. MASSEE

A.—Tree Fruits.

Records have been made of Apple Blossom Weevil (*Anthonomus pomorum*) to discover the rate of reinfestation following the almost complete control obtained by routine farm spraying with DDT in 1948.

Inoculations have been made in the insectary to determine the resistance of certain apple root-stocks to attacks of Woolly Aphid (*Eriosoma lanigera*).

Further spraying trials for the control of caterpillars of the Winter Moth and Tortrix groups have been carried out at East Malling and in collaboration with the N.A.A.S. (Eastern Province) to compare the effects of DDT applied with DNOC and in the green-cluster lime-sulphur ; also parathion in the green-cluster lime-sulphur spray.

Biological studies of the Apple Sawfly (*Hoplocampa testudinea*) have continued. A field spraying trial has been carried out to determine the effect of applying parathion at various dates after petal-fall.

The special investigations on the Fruit Tree Red Spider mite (*Metatetranychus ulmi*) are being continued at the Field Laboratory, Great Braxted, Essex, and at East Malling.

Studies of the life-cycle of the mite confirm and supplement the results obtained in 1948. The perfect weather conditions enabled the mite to breed and multiply throughout its five generations. Work has also been done to establish the type of leaf damage caused by the mite.

The dispersal phase of the Fruit Tree Red Spider mite has been investigated with a view to finding the times at which, and the conditions when, the mites disperse. Modifications of the methods used for trapping the mites have enabled more reliable data to be obtained. A wind tunnel has been constructed to enable the movements of the mites to be watched more closely under laboratory conditions.

The predator aspect of the mite (D.217) has been studied as a whole, rather than as an investigation of the life-cycles of the species. The problem has developed into one concerning the fluctuations of populations of predators and mites throughout the season, and from one season to another. The environmental factors, weather conditions, orchard spraying programmes and tree conditions are being taken into account. A new method of estimating insect populations in the field is also being made.

Summer spraying trials have been carried out at two centres in Essex, at Runsell Green and Writtle. At Runsell Green early applications of parathion and diphenyl sulphone were compared with later applications of the same sprays, and valuable information has been obtained. At Writtle the use of new acaricides resulted in very satisfactory mite control, but the experiments also emphasized the dangers associated with the destruction of predaceous insects of the mite (see VII. B). Field and laboratory tests of little known and new acaricides have been extended to summer field trials (see VII. A).

A detailed catalogue of the world literature of the mite and the predators has been completed in collaboration with the Commonwealth Institute of Entomology and is now in the press.

Experiments are being made to study the effects of DDT and various other insecticides upon beneficial and pollinating insects associated with fruit.

In collaboration with the Plant Protective Chemistry Section, chemical tests are being made of the persistence of DDT and parathion residues (see VII. A).

Investigations on the control of the Nut Weevil (*Balaninus nucum*) are being continued in collaboration with the Pathology Section. The use of DDT dust has given promising results in the past two seasons.

A study of the biology of all species of Apple Aphids has started.

Work is in progress on the life-cycle of the Codling Moth (*Cydia pomonella*), including the emergence period in orchards and packhouses. Overwintering situations of larvae are being studied and various types of bait traps tested.

A field trial of improved control measures for the Red Bud Borer (*Thomasiniana oculiperda*) has been planned following the promising results of small-scale experiments.

B.—Small Fruits.

Strawberry.

Studies of the bionomics of the Strawberry Eelworm (*Aphelenchoides fragariae*) are continuing and a trial designed to assess its effect upon yield has been established. The possibilities of control by systemic insecticides and by other means are being explored. Several cases of damage by the Stem Eelworm (*Ditylenchus dipsaci*) have been investigated. This species has hitherto been little known as a pest of strawberry ; a study of its economic significance is, therefore, being made, together with preliminary work on control measures.

Laboratory and field trials have given much information on the effects on the Strawberry Aphid (*Pentatrichopus fragaefolii*) produced by parathion and bis (bisdimethyl amino) phosphonous anhydride.

Collaboration with workers at the Imperial College of Science has continued to assess the value of methyl bromide as a fumigant against Strawberry Tarsonemid Mite (*Tarsonemus pallidus*).

In the study of the fauna of cultivated strawberry further insects have been recorded, and the habits of some of them are being worked out.

Raspberry.

Field trials on the control of the Raspberry Cane Midge (*Thomasiniana theobaldi*) have yielded information on the formulation and application of benzene hexachloride and on the comparative value of parathion. The results of the past three years' biological studies are now ready for publication.

Black Currant.

Biological studies of the Black Currant Midge (*Dasyneura tetensi*) have revealed seasonal variations which complicate the timing of control measures. Field trials of new insecticides are in progress.

Ribes Aphids.

Biological studies have continued. A small field trial was carried out to assess the value of parathion as an alternative to winter spraying.

Systematic Study of Gall Mites and Red Spider Mites.

A study of the mites in these two groups is being made, and several species have been found which are predators of the Fruit Tree Red Spider mite.

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——— **Apple blossom weevil.** Amateur Gardening, 1949, **65**, 16 (D215).

MASSEE, A. M. **Notes on some interesting insects observed in 1948.** Rep. E. Malling Res. Sta. for 1948 (1949), 102-7 (D216).

COLLYER, ELSIE. **The predator aspect of the Fruit Tree Red Spider problem.** Rep. E. Malling Res. Sta. for 1948 (1949), 108-10 (D217).

MASSEE, A. M. **Ova of** *Metatropis refescens* (*Hemip., Berytidae*). Ent. mon. Mag., 1949, **85**, 103 (D219).

——— **Notes on mounting and collecting the** *Hemiptera-Heteroptera.* Ent. mon. Mag, 1949, **85**, 152-6 (D220).

(See also V., C253.)

VII. PLANT PROTECTIVE CHEMISTRY

By A. H. M. KIRBY

A.—Laboratory Investigations.

Persistence of DDT and Parathion Residues.

The impression of growers and entomologists that DDT applied in dormant oil sprays lasts longer when it is dissolved directly in the oil than when it is added as a wettable powder to the oil emulsion in the spray tank, has been confirmed by biological and chemical assays of the residues on twigs. Both methods indicate that more DDT adheres in the first case ; the amount of DDT entering the bark is small in either.

Even less DDT adheres when it is applied as a wettable powder in 2 per cent. lime-sulphur. Less DDT was present three weeks later than after ten weeks in the case of DDT applied in oil.

When parathion was applied in a 2 per cent. lime-sulphur wash, the rate of loss was very great. Little parathion could be detected chemically after three days and none at all at sixteen days.

Action of Metallic Salts on Lime-Sulphur.

Determinations of the polysulphide sulphur remaining in the supernatant liquid after various salts had been added to 1 per cent. lime-sulphur showed that ferrous, zinc and manganese salts precipitate 70 to 95 per cent., but magnesium salts only 10 to 25 per cent., of the polysulphide sulphur. Glass slide tests, using *Venturia inaequalis* and *Botrytis allii*, showed striking differences in the fungicidal action of such mixtures ; in some instances the activity was enhanced, in others it was reduced or even abolished. Probably only field tests would give a true picture of the effects produced.

Mechanism of Ovicide Action.

The effect of an ovicide may be achieved in certain eggs simply by suffocation ; in most cases with which we have to deal, however, the efficiency of an ovicide depends upon (*a*) inherent toxicity to protoplasm, and (*b*) ability to penetrate the protective layers round the protoplasm. Studies have been made of a few substances which might be expected to improve the situation under (*b*), thus enabling the toxic agent to reach the site of action.

In the case of winter eggs of the Fruit Tree Red Spider mite, benzyl alcohol (non-toxic) was found to enhance the action of azobenzene, azoxybenzene, *n*-dodecyl thiocyanate, diphenylamine and di-(*p*-chlorophenyl) methyl carbinol (DMC).

When the summer eggs of this mite were used, a definite antagonism was found in spite of the fact that benzyl alcohol alone displayed an inherent toxicity.

Two other possible penetrants were tried with the summer eggs. Piperonyl butoxide, well-known as a synergist for pyrethrum, showed some inherent toxicity, but caused no significant increase in the toxicity of azobenzene. Hexylene glycol was also useless.

Benzyl alcohol and carbitol were tested against the eggs of *Aphis pomi*, Deg., using alkyl thiocyanate as potential ovicide. Both agents proved toxic and showed no evidence of improving the action of alkyl thiocyanate.

Mechanism of Insecticide Action.

Preliminary experiments on the action of benzyl alcohol as a penetrant for insect cuticle have been carried out using diphenylamine and parathion as insecticides and *Tribolium confusum* as test insect. Increase of benzyl alcohol increased the kill by diphenylamine, but addition of this penetrant to parathion caused very erratic results.

Fungicide Studies.

The toxicity of aqueous extracts of ivy, *Hedera helix*, towards *Venturia inaequalis*, demonstrated at Oxford, has been confirmed ; concentrations inhibiting spore germination in this organism were, however, stimulatory in the case of *Botryis cinerea*.

Laboratory studies indicate that the mercury salt of a decomposition product of TMTDS is slightly more active than the corresponding quantity of mercury in the form of phenyl mercury chloride against *V. inaequalis*, but the desirability of the use of mercury in any form on fruit is debatable.

The whole problem of scab control is complicated by the great variability of the fungus in the field, and this is reflected in the difficulty of getting satisfactory supplies of spores in the laboratory for screening tests. An extensive programme has, therefore, been undertaken in which monoconidial isolations of *Venturia* spp. are being made in order to study the relation, if any, between morphology and pathogenicity and to evolve suitable artificial media for the culture and sporing of these organisms ; the reactions of different strains to selected fungicides will be studied in the laboratory.

B.—Field Studies.

Fungicide Trials (see also V.).

There was no significant difference in Scab equivalent or percentage of infected fruits on pear trees, variety Williams', given the following sprays in addition to the normal farm schedule :

(*a*) Bordeaux, 4-6-100 (1 lb. copper per 100 gallons).
(*b*) 341C (heptadecyl glyoxalidine acetate, 37 per cent.) 1 quart, plus ½ lb. slaked lime per 100 gallons.
(*c*) Dinitrophenyl capryl crotonate, 0·1 per cent. as a 25 per cent. wettable powder.
(*d*) Copper cuprosulphite, 2·4 lb. (1·2 lb. copper) per 100 gallons, plus methyl cellulose 0·0025 per cent.

No damage was caused to fruit or foliage, and a further trial is envisaged using these materials in place of the regular schedule.

Cox's Orange Pippin trees on M.IX, which had received one pre-blossom treatment with 1 per cent. lime-sulphur, were sprayed twice post-blossom to assess the fungitoxic action of a number of promising materials against Apple Scab. Best control on fruit was given by zinc dimethyl dithiocarbamate ; two grades of alkyl glyoxalidines, 341C and 341SC, ferric dimethyl dithiocarbamate and zinc ethylene bisdithiocarbamate, Z78, came next, followed by 1 per cent. lime-sulphur, TMTDS, dispersible sulphur and phenyl mercury chloride, with zinc monoethyl dithiocarbamate and dinitrophenyl capryl crotonate giving least control. On leaves, there was no significant difference in control among the treatments, except that the last two and dispersible sulphur gave definitely poorer results. No effect on fruit set, fruit drop or leaf drop was seen with any treatment.

The value of glyoxalidine 341C for control of scab was compared post-blossom with that of lime-sulphur, phenyl mercury chloride and dispersible sulphur on large trees of Cox's Orange Pippin, on a variety of rootstocks, which had received 2½ per cent. lime-sulphur once throughout pre-blossom. Dispersible sulphur caused least leaf-fall but gave poorest control of scab on fruit. Leaf-fall due to 341C was not significantly greater than that due to dispersible sulphur, and control of scab was at least as good as that given by lime-sulphur or phenyl mercury chloride. Judged by one season's work on a limited scale, glyoxalidine 341 C is definitely promising and will merit further study.

Insecticide Trials.

(*a*) *Woolly Aphid.* A comparison of the control given by a commercial 5 per cent. benzene hexachloride dust, 0·0075 per cent. parathion, and 0·1 per cent. bis (bisdimethylamino) phosphonous anhydride, applied just prior to the first earthing-up, was made on M.XVI rootstocks in an established nursery, using unsprayed stools as controls. Infestation was high throughout the area when the treatments were applied, and when the rootstocks were harvested it was found that 60 per cent. of the controls were galled. Stocks from parathion-treated stools were 50 per cent. galled, but only 15 per cent. bore galls where benzene hexachloride had been applied. Of six rows of stools sprayed with the anhydride, three bore stocks free from galls, and very small galls were present on only six out of 350 stocks on the rest. There is, therefore, reason to believe that any variety of rootstock could be kept free of Woolly Aphid by a single application of this organo-phosphorus compound just prior to earthing-up. This insecticide is systemic in the plant and overcomes the difficulty of wetting this pest.

(*b*) *Apple Sawfly.* Parathion, applied at 0·024 per cent. in the post-blossom lime-sulphur spray, gave 90 to 95 per cent. control of this pest on commercial trees of Worcester and Cox's Orange Pippin. Premature yellowing and fall of primary leaves was seen on Cox in proportion to the strength used, but was never serious. The farm nicotine spray gave no control of sawfly, even where derris was also applied three weeks later. 0·00125 per cent. parathion applied at egg-hatch, which was nine days after 80 per cent. petal-fall, gave as good control as 0·005 per cent. applied at petal-fall. Observations on fruitlets brought into the laboratory indicated that neither nicotine nor parathion killed the eggs, but only the larvae on hatching. Fruit-set and fruit-fall (other than infested fruits) were not significantly different among the three parathion strengths employed. The value of a persistent insecticide for sawfly control is thus emphasized, but at present it would be unwise to regard parathion as the insecticide of choice.

(*c*) *Codling Moth.* A large trial for control of this pest was carried out on Charles Ross and Worcester trees, using 0·2 per cent. lead arsenate as standard. Other treatments were 0·2 per cent. zinc fluoroarsenate, 0·1 per cent. DDT plus 0·1 per cent. diphenyl sulphone (DPS), 0·1 per cent. DDT plus 0·01 per cent. parathion, 0·01 per cent. parathion, and 0·1 per cent. dinitrophenyl capryl crotonate. All treatments gave a marked reduction of infested drops compared with unsprayed controls. Lead arsenate was probably superior to the zinc compound on both varieties but inferior to DDT plus either parathion or DPS. Parathion alone and dinitrophenyl capryl crotonate were effective on Worcester, but rather poor on Charles Ross.

Although application of DDT in June could be expected to cause a build-up of red spider by elimination of predators, a count of adult females (mangle record by Entomology) five weeks after application of treatments showed least mites on the DDT-plus-DPS trees of both varieties. A late count of winter eggs showed that, while the egg population was considerable on all trees, the arsenate-treated trees bore much the same numbers as the unsprayed controls, whereas those receiving all other treatments carried higher populations, DDT-plus-DPS having the highest on either variety. Careful records of red spider populations as well as codling moth infestations are clearly needed in these trials.

Fruit Tree Red Spider Investigations.

Pure diethyl *p*-nitrophenyl phosphate, E600, was found to be significantly more toxic to the summer forms than a substantially pure sample of parathion ; another analogue, diethyl *p*-chloro-*m*-methyl phenyl phosphate, was inactive. *N*, *N*-amyl benzyl and *N*, *N*-amyl benzoyl derivatives of *cyclo*-hexylamine were promising, but the *N*-amyl derivative was not so good. Dinitrophenyl capryl crotonate was also very promising. The following were found poor or useless : *m*- and *p*-cresyl benzoates, glyoxalidines 341C and 341SC, benzoyl anilide, γ-benzene hexachloride, chlordane and toxaphene.

Field trials of acaricides, promising in earlier laboratory tests, were carried out in Essex (see also VI). Alkyl thiocyanate, containing 48 per cent. *N*-dodecyl ester derived from synthetic alcohol, proved at least as effective as the standard 3 per cent. petroleum spray against the winter eggs, without damage to the trees (Worcester) or prejudice to predator population. Against the summer forms, parathion applied on Cox early or late at 0·005 per cent. gave considerable control and good crop records, but was inadequate to prevent later mite build-up. Diphenyl sulphone, formulated as a wettable powder, failed to sustain its promise of 1948, whether applied early or late and with or without derris. Parathion at 0·06 per cent. destroyed all insects and mites and exhibited a marked residual action, but final mite populations on these trees were exceptionally high. Azobenzene at 0·03 per cent. and alkyl thiocyanate at 0·2 per cent. (crude) each gave reasonable control, but not so good as that given by DCPM at 0·09 per cent. Benzyl benzoate, at 0·1 per cent., gave only moderate control at first, but late build-up on these trees was least of any treatment due to the relatively slight toxicity towards the predators.

Phytotoxicity Trials.

Fourteen substances were tested at the Station for phytotoxicity to Cox, and, of these, 12 were also tested on Worcester. None of the sprays caused damage on Worcester. On Cox, azoxybenzene at 0·1 per cent. and alkyl thiocyanate at 0·4 per cent. (crude) caused necrotic spotting ; this damage was slight when the thiocyanate was applied at 0·2 per cent. (crude). Early yellowing and leaf-fall were seen on unsprayed Cox on this Plot during the season, but this form of damage was enhanced by lime-sulphur plus lead or aluminium arsenate or zinc fluoroarsenate ; glyoxalidine 341C plus lead arsenate was quite safe, however. A manufacturer's formulation of DMC caused definite damage at 0·2 per cent. Copper cuprosulphite, at 0·15 per cent. copper content, caused little or no damage ; nor did DDT, toxaphene and T.P. 13, each at 0·1 per cent. active ingredient. Glyoxalidines 341C and 341SC applied at double the strength recommended for scab control were quite safe.

In Essex, the five sprays used for acaricidal trials on Worcester were also applied to Cox in an adjacent orchard at the same time. Azobenzene, benzyl benzoate and parathion caused slight premature yellowing and fall of primary leaves ; this damage affected about 5 per cent. of the parathion-treated leaves by a fortnight after spraying. Thereafter, leaf-fall did not increase and was never serious. There was no fruit-fall attributable to spray treatments.

PUBLICATIONS DURING THE YEAR.

EATON, J. K. **The insecticidal properties of certain organo-phosphorus compounds.** Nature, 1949, **163**, 496-8 (Q50).

DAVIES, R. G., and EATON, J. K. **The effect of hydrogen-ion concentration on the ovicidal activity of some nitrophenol emulsions.** Rep. E. Malling Res. Sta. for 1948 (1949), 111-7 (Q52).

VIII. HOPS

A.—Varieties and Cultivation Trials.

By F. H. BEARD

Commercial Varieties.

The final (sixth) season's records have been made on the clonal Golding trial. Much information has been obtained over the period. The data are now being summarized and prepared for publication. Sets of the seven East Malling Golding clones have been planted at Wye for comparison with other clones.

Cuts of 40 Fuggle clones have been sent to Wye and will be intensively propagated for planting in a new Fuggle strain trial. Included in the trial will be selections of Fuggles known to be definitely earlier in season than normal and others thought to have especially good cone development. The best East Malling Fuggle, strain " N ", described in the Annual Report for 1943, will be included as a standard of comparison.

New Varieties.

The crops from around 85 new varieties raised by Professor Salmon at Wye were picked and dried separately so that the yields could be calculated and, where necessary, samples saved for P.V determinations. Samples of 19 varieties were placed in air-tight glass jars for subsequent analysis. The latest analytical data show that, on the whole, varieties had a considerably higher P.V. in 1949 than in 1948. Nonsuch hop (OM26) had the highest P.V. (113), whilst John Ford (WFA90) and Brewer's Gold (C9a) were only slightly lower.

Cultural Trials.

The time of cutting and severity of pulling trial has been concluded. In the past season there were no significant differences between the treatments, though there was a suggestion that the plots with the more forward bine gave heavier yields.

Out of eleven seasons, in six there have been no significant differences between treatments ; in four seasons the plots with the more forward bine gave heavier crops ; but in only two seasons has " time of cutting " had any effect on the yields.

In the trial designed to compare methods of checking the extreme vigour of Brewer's Gold, the cropping of the two " stopping " treatments in 1949 did not differ significantly from the control. Wide spacing did, however, reduce the yield. In the previous season, both " stopping " and wide spacing gave yields lower than the control. Both 1948 and 1949 have been unsuitable seasons for this trial as, in both, Brewer's Gold failed to make its usually ultra vigorous growth.

The effect of cutting the bine at picking time, necessary when hops are picked by machine, is being investigated on Bullion Hop. In 1949 those plots cut at picking time in the previous season gave a slightly lower yield than the control plots. The trials with Brewer's Gold and Bullion will be continued at East Malling for a year or two until comparable trials are established at Wye.

B.—Diseases of Hops.

By W. G. KEYWORTH and J. PAINE

Some seven new outbreaks of progressive Verticillium Wilt have been reported to the Research Station during 1949, mainly by inspectors of the Ministry of Agriculture. Two of the new outbreaks are a few miles from the main affected area in Kent and Sussex, but there is no evidence of spread to any completely separate hopgrowing district.

Presumably because of the hot dry weather during the growing season, fluctuating Verticillium Wilt was much less prevalent in 1949 than in the previous year. For the same reason the masking of Nettlehead symptoms was very pronounced.

During a visit to the hop-growing areas of the West Midlands, virus-infected plants suitable for experimental work were marked for collection in the winter. Surveys of several hop yards were made and a site selected for a future experiment.

Verticillium Wilt.

Some 20 new seedlings bred from resistant parents were given their first standard resistance trials during the year. Several of them appeared highly resistant and also of fair cultural quality. They included a number of male hops which may be of value, both for planting in infected gardens and for further breeding work. Other new seedlings were further propagated for resistance trials in 1950.

Some 20,000 sets of the older established resistant variety OR55 (Keyworth's Midseason) were distributed by the Hops Marketing Board to 15 hop growers early in 1949. Records made of these plantings, together with those of older plantings both of OR55 and of OJ47 (Keyworth's Early) showed that the wilt incidence in either variety under commercial conditions averaged about 2-3 per cent. In several of the two- to three-year-old gardens of these varieties it was noted that some of the plants which had shown wilt symptoms in 1948 were now apparently unaffected. This confirms previous observations and suggests that plants of these varieties may show recovery from the effects of the disease as they become established.

A description was published of two experiments, which were made in collaboration with the Long Ashton Research Station from 1944-47, on the effect of *Verticillium albo-atrum* on hops growing in sand culture supplied with various nutrient solutions. In both experiments, nitrogen-deficient plants showed much less severe symptoms than those grown in complete nutrient. Other modifications of the nutrients supplied did not result in any consistent or marked alteration in the final symptom status of the plants (C.245).

Following on this work a series of experiments was started using hop plants grown in a plot of ground deficient in nitrogen, to which various nutrients were added. These trials have shown nitrogen effects, similar to those noted in the pot experiments.

Virus Diseases.

Research in 1949 was mainly directed to the determination of the natural vectors of Mosaic and Nettlehead. As research on the vectors of the hop virus diseases found in Czechoslovakia had already been carried out by Dr. C. Blattńy and his colleagues, a visit was paid in July to the Hop Institute at Zatec to study this work at first hand. Information of considerable value in the planning of our own work was obtained.

Experiments involving the artificial transfer of insects in the glasshouse were again greatly hampered by limitation of space and by lack of temperature control. Under the abormally hot weather of 1949, almost complete symptom-masking occurred both in the glasshouses and in the field. Thus no conclusion could be reached on the 1948 tests of *Phorodon humuli* as a vector of Nettlehead and Mosaic. Seven other insects and the Hop Eelworm and Red Spider were tested this year, but no evidence of transmission has yet been obtained.

Besides the direct transmission experiments with individual insects, a study of the spread of hop virus diseases in the field was started in a series of observation plots selected in hop gardens where the diseases appeared to be spreading. A field trial on varietal resistance to Nettlehead was also started. Earlier work suggested that certain Wye Seedling varieties might be partially tolerant to graft-infection with Nettlehead. The present trial is designed to test the reaction of six of these varieties to *natural* infection.

PUBLICATIONS DURING THE YEAR.

SALMON, E. S. **Thirty-second report on the trial of new varieties of hops.** 1948 (1949) (B65).
BEARD, F. H. **Hop growing.** Progressive Farming (1949), 1, Chap. 7 (B66).

(See also V., C239, 243, 244, 245 and 255.)

IX. SCIENTIFIC LIAISON SECTION

By H. B. S. MONTGOMERY

Collaboration with the official advisory services has been working smoothly throughout the year and has led to a reduction in the routine advisory work of the Section, especially as regards postal enquiries, of which almost 20 per cent. were referred direct to the advisers. In addition, the advisers have been kept informed of all replies sent out, including those about research in progress. Telephone enquiries for advice show a slight reduction on the totals for previous years.

All but a small number of the very many requests for visits to the Station were satisfied. In all 72 parties were shown round, including 6 overseas parties ; 845 individual visitors were received, many of whom, being scientists from overseas, required special programmes. Wherever possible individual visitors with common interests were grouped together to form small parties. Members of the advisory services have attended rehearsals for our Members' Days or the actual Days, and a special two-day course was arranged for a third of the N.A.A.S. horticultural staff. This course is planned as an annual fixture and will ensure that each horticultural officer visits the Station at least once every three years. Courses for officers concerned with the certification of fruit tree rootstocks and hops have been maintained.

Eight popular articles were contributed by members of the Section, and help was given to the research staff who wrote a further twenty-six articles of this kind. Much assistance has been given to the Ministry of Agriculture in producing and keeping up to date the official fruit bulletins and leaflets, and to the Royal Horticultural Society in the preparation of the book *The Fruit Garden Displayed*. The Section has assisted with judging at all the leading commercial and amateur fruit shows in Kent.

Our three ciné films, though produced prior to 1941 with very simple equipment and little experience of film making, are still in constant demand, demonstrating the great dearth of reliable films on fruit growing. One film, stub-grafting, was sent on loan to Paris for showing to French fruitgrowers. Our wide collection of photographs and slides has been frequently used to assist advisory officers and educationalists in giving lectures, teaching, preparing exhibits and illustrating articles. Exhibits have been prepared and staged at sixteen horticultural shows including the Chelsea Flower Show. Lectures on various aspects of the Station's work were given at Fareham (Hants), Taunton (Somerset), Sutton Bonington (Nottingham), and Gravesend (Kent).

Service on outside committees continues to be an important part of the Section's activities, especially the Fruit Group of the N.A.A.S., the Horticultural Development and Education Sub-Committee of the National Farmers' Union, the Fruit Committee of the Horticultural Education Association, and the Horticultural Sub-Committee of the Kent Agricultural Executive Committee.

The Section has again organized the series of sixty lectures given to the plantation assistants at the Station. Unfortunately the joint work with the Kent Education Committee in training Kent school teachers in fruit gardening has been terminated owing to the resignation of the instructress concerned.

As time permits, members of the Section are undertaking specific research problems under the Research Sections concerned, especially peach culture (see I, p. 26).

In addition one member of the Section has advised and assisted the Farm staff in improving the packing shed organization and the handling and marketing of the fruit. Help has also been given to the Marketing Branch of the Ministry of Agriculture in testing suggested grades for marketing strawberries.

Publications during the year.

Montgomery, H. B. S. **The Oeschberg pruning method.** N.A.A.S. Quarterly Review, 1949, No. 3, 125-7 (T12).

——— **East Malling had its money troubles.** Grower, 1949, **31**, 303-5 (T13).

Painter, A. C. **Storing apples and pears in the home.** Kent County Garden Produce Year Book, 1949, 24-5 (T14).

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A.R.C. SCOTTISH RASPBERRY INVESTIGATION

By R. V. HARRIS and C. H. CADMAN

A.—Plant Pathology.

Virus Diseases.

This year it was found that two viruses can readily be transmitted by their aphid vector, *Amphorophora rubi*, to the black raspberry, *Rubus occidentalis*, and also to the native stone bramble, *Rubus saxatilis*. Using commercial red raspberry varieties, it had previously been found extremely difficult to make any satisfactory progress in the accurate analysis of raspberry virus complexes. This year's work has, however, given a new approach to the problem and has provided evidence indicating that earlier difficulties were due to an inherent resistance of red raspberry varieties to aphid-borne infection.

A comprehensive body of information on the viruses infecting raspberries in Scotland has now been assembled and an account of sections of this work is being prepared for publication.

Investigation, by the grafting technique, of the virus complexes causing " symptomless degeneration " of tolerant varieties, more particularly of the Lloyd George variety, has reached a stage where certain virus combinations can be singled out as being of most importance. Attempts were made this season (*a*) to find out which of these regularly occur in degenerate stocks and (*b*) to synthesize the complexes from their components.

Field studies of the rate and manner of spread of individual viruses were continued and more detailed studies of this problem are planned for next season.

Stock Testing Work. The large scale propagation scheme for the New Zealand stock of Lloyd George mentioned in the 1946-47 report is now in operation (see section C below). Samples from the daughter stocks propagated in Strathallan, near Auchterarder, indicate that the stock is still free from serious virus infection.

The selections of St. Walfried, Malling Promise and Landmark, described in last year's report as virus free, and now in the course of propagation, were re-tested and found still to be free from serious virus infection. The qualification " serious " is necessitated by the discovery of an unidentified virus in our tested stocks of Lloyd George and Malling Landmark.

The parent stocks of twelve of Mr. Grubb's new seedlings received from East Malling Research Station were also graft tested.

In addition to these routine tests, selections from a good stock of Burnett Holm Seedling were tested prior to propagation.

Fungus Diseases.

The spraying experiments for the control of Cane Spot, which are being concluded this year, were designed this season to provide information on (1) the comparative efficiency of Bordeaux mixture (4 : 6 : 100) and lime-sulphur (2½ per cent.) sprays, and (2) the effect of dosage and time of application on the efficiency of lime-sulphur sprays. An account of the work carried out over the past five seasons is being prepared for publication.

B.—Entomology.

A repetition of last season's trials of insecticides for the control of the Clay-coloured Weevil (*Otiorrhynchus singularis*) confirmed the efficiency of a 0·4 per cent. DDT wet spray, applied at 300 gallons per acre, and alternatively, of 10 per cent. DDT dust, applied at 70 lb. per acre, as a control measure for this pest.

Owing to the low infestation of Raspberry Moth (*Lampronia rubiella*) this season, no useful results were obtained from an extensive series of spraying and dusting experiments carried out in the early part of the year. These experiments will be repeated.

Laboratory and field work was devoted mainly to a study of the biology of *Amphorophora rubi*, the aphid which appears to be the principal insect vector of raspberry viruses. Last season's finding that populations of British *A. rubi* consistently failed to thrive on plants of American red raspberry, *Rubus strigosus*, has been followed up by glasshouse experiments on the behaviour of populations of this aphid on different varieties of *Rubus idaeus* and other *Rubus* species. The numerical size of the population resulting from single mature viviparae of *A. rubi* in twenty-eight days was used as an

index of resistance to infestation on the part of the host plant, and on this basis there appear to be consistent differences between the varieties and species examined.

In the field, data were collected on the migration of and fluctuations in the populations of *A. rubi* in a commercial fruiting plantation as compared with an isolated propagation bed. This work was supplemented by trap records and collections from wild *Rubus* hosts in Angus and Perthshire.

C.—Horticulture.

Nuclear Stock Propagation Schemes.

With the closing down last season of the isolated cane nursery experiments, our various special stocks are now being propagated for the Investigation by a number of growers in Scotland on a contract basis.

One distribution of the New Zealand Lloyd George stock has already been made to various propagating centres in the United Kingdom, while a harvest of some 30-40,000 canes is expected this season from the cane nursery at Strathallan Castle, Auchterarder. A further acre of this stock was planted at the Strathallan centre in February, 1949.

The plan underlying the propagation scheme for the production of pedigree stocks has now been accepted by the Ministry of Agriculture and Fisheries and the Scottish Department of Agriculture as a feasible basis for the certification of those tolerant varieties which cannot adequately be dealt with by the ordinary certification schemes.

Arrangements are now in hand for the bulking of tested stocks of the varieties Malling Promise, Malling Landmark, St. Walfried and Malling Exploit* (Seedling X). It is anticipated that stocks of the first two of these will be available for distribution in autumn, 1951, and of the second two in autumn, 1952.

In response to the increased demand for sound stocks of Malling Enterprise and Malling Jewel* (Seedling J) small nursery beds of each of these varieties were again planted.

Field Trials of Raspberry.

The main trial of commercial varieties planted at Slatefield, Forfar in 1947, yielded its second crop this year. With an absence of late frosts and a generally good growing season, the total yield from the two acres has been high, about $4\frac{3}{4}$ tons. Of the individual varieties, Malling Promise cropped at $3\frac{1}{2}$ tons per acre, followed by Lloyd George (Amos strain), Malling Landmark and Malling Jewel (J) each at 2-$2\frac{3}{4}$ tons per acre.

Malling Exploit (X) again proved to be an outstandingly heavy cropper among several newer seedlings not included in the main trial.

The New Zealand strain of Lloyd George outcropped Malling Promise in the first year of a small unreplicated trial of these varieties at Forfar.

The subsidiary trial planted at Auchterarder in 1947 suffered severely from drought and, under these conditions, Malling Landmark and Norfolk Giant proved the heaviest croppers.

A new trial which includes New Zealand Lloyd George, Malling Promise, Malling Exploit, Malling Seedlings V, W, Y and Z and six other new seedlings produced by Mr. Grubb and selected by Dr. Wood at East Malling in 1946, was planted at Kirriemuir in the spring.

Through the co-operation of Messrs. Chivers & Sons, S. W. Smedley, and Fromac, Ltd., canning and quick-freezing tests have been carried out on some sixteen different varieties and seedlings included in our trials. The results, which are not yet complete, indicate that Norfolk Giant, Lloyd George, Malling Jewel (J) and Burnett Holm Seedling are best canning varieties, whilst Malling Exploit (X) and Seedlings M and Y are rated highly for quick-freezing. These assessments are subject to modification following a further season's tests.

Publications during the year.

(See V., C242, 247, 250 and 251, p. 41).

* See p. 75.

Section III

RESEARCH REPORTS AND REVIEWS

GENERAL

AMOS MEMORIAL LECTURE*

THE SOIL AND THE FRUIT TREE

By B. S. FURNEAUX

In delivering the first Amos Memorial Lecture, Captain R. Wellington paid eloquent tribute to Jesse Amos, with whom he had worked side by side to found the East Malling Research Station. I, too, had the very great privilege many years later of working with Jesse myself. Belonging to a younger generation, it was my great good fortune to learn some of my earliest and most fundamental lessons on fruit growing from him. I learnt them in those surroundings where he was at his best—out in the orchards and plantations.

Captain Wellington emphasized Amos's outstanding talent as a grower. It was just this talent, and his ability to see where scientific knowledge fitted in to practical growing that made his friendly counsel so invaluable in the early days of the Fruit Soil Survey. In this piece of work, members of the staffs of Wye College and the East Malling Research Station collaborated in an assault upon that problem with which Captain Wellington closed his lecture. He said, " A much greater study of the effect of the soil is required ; we lag behind in new knowledge on this." It is true that in the five thousand years that man has been cultivating the soil, it is quite remarkable how little he has learned about this raw material upon which his very civilization is built up. Nevertheless, I cannot agree with Captain Wellington that : " Our means of rapidly assessing the value of a soil are almost negligible."

The progress made may not have been startling, but at least it has been sound. Within the last couple of decades a line of approach has been opened and we now know in what direction we are aiming. We have started on the way, whereas when the Fruit Soil Survey began in 1928, we had not the slightest inkling of where our path would lead, nor how we should attack our problem. I recall that at the time Dr. Hatton said, could we but find out what type of soil would grow dessert apples, we should have made a big contribution to the fruit growing industry. We have still far to go along the road towards knowing the full effect of the soil upon the fruit tree, but at least we have made a beginning. To-day I want to outline briefly the principles upon which that beginning has been established.

The soil as the environment of the fruit tree.

One of the chief difficulties in the study of our crops is that only a part of them shares with us the environment in which we live. The branches, leaves and fruit are in the air ; we can see them and we, of our own experience, know something of the conditions they enjoy. But workers at this Research Station have shown that the greater part, possibly two-thirds, of the tree is below the ground. We have only the most hazy notion of what conditions are like there. Thus we are apt, when we study our orchards, to have an unbalanced picture, to have always the aerial portion of the plant in mind, and to forget the greater unseen part.

It is so comforting to be able to blame anything we cannot explain upon the soil. It salves our consciences and we feel quite safe that nothing can prove us wrong. We have collected some detail about the soil and what goes on in it, and we must now try to piece together the information so that we can understand the conditions in which our trees are living. We must realize that, in developing their root systems, our trees must accommodate themselves to the soil conditions as they find them. These may differ enormously from place to place.

* The second Amos Memorial Lecture, delivered in the Great Hall, Bradbourne, on Tuesday, 18th October, 1949.

The first and simplest effect of the soil upon the tree is to control the amount of space that this below-ground portion has to live in. The soil depth may vary from a few inches to several feet, and consequently the tree may be capable of developing a large root system or one in only the most cramped of quarters. This, in itself, has a distinct bearing on the vigour of growth.

If we attempt to bring the requirements of the plant as clearly as possible into terms that we ourselves readily understand, we can do so by realizing that, like ourselves, our crops require air, water and food. Not only do the leaves require to breathe, but also the roots, right down to their deepest tips. If the air is shut out for any length of time they suffocate and die. This can easily be seen in soils which become waterlogged. When the water rises during the winter and drives out the air before it, the roots are killed by drowning just as we should be. If we manage our soil badly and produce a cultivation pan which obstructs the free entry of the air into the soil, we may produce an almost similar effect.

If the roots of the fruit tree are to perform their functions efficiently, they must be able to breathe readily. This is one of the most important facts in considering the suitability of a soil for fruit growing. How often have fertilizers been applied to the soil when all the crop really needed was air ?

After a season like that we have just experienced, there is little need to emphasize the dependence of our crops upon their supply of water. The soil must act as the reservoir which will hold sufficient moisture to tide the crop over from one fall of rain until the next. In so doing, however, it must allow any surplus to run away and not let it accumulate. The reservoir capacity of the soil depends upon a number of things, of which one of the most important is its depth. The deeper the soil the more water it will hold : consequently, in a year like this one, it is on the shallow soils that our crops have suffered and on the deep ones they have looked surprisingly well. Naturally, the water-holding capacity of light soils is smaller than that of soils of heavier texture. Consequently, upon these soils depth becomes of even greater importance. To retain the full amount of moisture of which it is capable, the soil must have a well-developed structure.

Many of our soils, however, do not have to rely entirely upon the rain which falls directly upon them. Subterranean springs are far more numerous than is generally believed, and many soils are moistened in their deeper layers with a seepage of water. This may, or may not, be an advantage to the crop growing there. Those which have a high moisture requirement, such as pears and blackcurrants, will flourish in such a soil, provided the seepage is not sufficient to cause waterlogging. Culinary apples, too, will crop and grow well on such land, but with dessert apples or cherries it is another story.

A continuous supply of moisture may also be provided by a permanent water-table. Although not much of our fruit in Kent is grown on land which possesses such a water-table, Wisbech growers are quite familiar with this condition.

The presence of subterranean water may lead to complications of nutrition. Springs which enter the soil from limestone rocks may carry sufficient calcium in solution to cause iron or manganese deficiency.

I can safely leave the matter of plant foods in the hands of my colleagues the chemists. They have made steady progress in the study of plant nutrition, and although our knowledge of this subject is still far from complete, the farmer is at least in the position that he can supply the major elements from a bag, having had analyses made to assist him.

The diversity of soils.

Had our sight the power to penetrate beneath the surface as we walked about our land, we should be surprised at the enormous variation in soil that occurs. At the surface most soils look much alike, but beneath they exhibit the greatest variety. In many respects they differ every bit as much as the plants which grow upon them, but it is a world that is hidden and we can only peep at it in a limited number of places.

A soil auger pulls out a core an inch in diameter, which is but a very small sample from which to picture an acre. Again, it is hard to examine a soil without destroying its structure. In spite of this, if we are to progress in our knowledge of soils, it is essential that we should be able to recognize them on the spot where they occur, without analyses or tests, just as a botanist can recognize a plant.

Of recent years a sound and reliable system has been developed and is now used internationally for recognizing soils. It must be realized that before any real advance can be made in the study of soils, each individual kind must be recognized and given a name. Until this is done it is impossible to accumulate in orderly fashion all the information about each different kind. The most convenient unit, and that which has been generally used to link up the different kinds of soil with their fruit tree

performance, is the Soil Series. All soils which are alike in five important characteristics are placed in the same Soil Series and given the same name. Briefly, these characteristics are :

(i) The geological origin of their mineral material.
(ii) The manner in which this has been converted into soil.
(iii) The natural drainage.
(iv) The position in the landscape.
(v) The soil profile (i.e. appearance of the soil when seen in section in a pit).

Many people imagine that the geological map is almost, if not absolutely, a map of the soil. The geological map is prepared for the benefit of those whose interest lies deeper than the first few feet, for the mining engineer or the well-sinker, rather than the farmer. It should be borne in mind that each geological formation may, and generally does, give rise to a number of soils differing very widely in their suitability for fruit growing.

On level country the forces of the atmosphere eat into and weather the rock, producing, with the aid of the plants which grow on it, a soil which is formed where it lies. Such a soil will usually be of moderate depth and will have every opportunity of developing to a state of maturity. On a steep slope, on the other hand, as fast as the atmosphere weathers the rock, the soil may be washed away. This process of erosion is enormously accelerated if man cultivates the land. In such a position only a shallow soil is formed and one which does not have the opportunity of reaching full development. At the foot of the slope this downwashed material accumulates, giving rise to a deep and incompact soil which is continually growing. Thus, through differences in the lie of the land, our one geological formation has given rise to three contrasting soils. In such a way, within a short distance, distinct types of soil may be found giving rise to land which may be excellent for fruit growing in one place, and only a few yards away almost useless.

The natural drainage of the soil depends to a large extent upon the character of the underlying geological material. If it is pervious and allows the free passage of water, the soil itself will drain freely too. On the other hand, it may obstruct the percolation and cause water to collect in the lower layers of the soil. Here a fruit tree would have its deeper roots drowned during winter, but would have no reserve of moisture for its crippled root system if drought followed. Thus, the tree would feel the worst effects of a dry summer. Contrast this with a soil which shows signs of poor drainage due to the passage of spring water through its lower layers. Here the supply of moisture continues during the growing period and produces vigour of growth. The permanent water-table may fluctuate widely, rising close to the surface during winter and drowning the deeper roots, then falling away during summer. In such a case it may be a detriment, but on the other hand it may remain more or less constant within easy reach of the roots, yet not so deep as to be beyond their grasp. Thus, once more, great diversity of soil conditions may be produced through differences of drainage.

All these factors make themselves shown in the soil itself, so that, if it is opened up in a pit or cutting, or even just an auger boring, the section so made reveals its major characteristics. This section is the soil profile, which is the summary of its very being.

The correlation of the soil and fruit tree growth.

With the power to recognize each kind of soil, it becomes possible to associate with the name of each its salient characteristics. Imagine for one moment the state of chaos there would be in fruit growing were none of the varieties of apple named. That was the state of soil science until each soil series could be distinguished from its fellows. In the Fruit Soil Surveys made in Kent the distribution of the various Soil Series was mapped in a large number of orchards. Then the pomologists came and recorded their observations on the trees. They also gathered the experience of a large number of growers. When it came to putting together tree growth and soil conditions, a remarkable degree of correlation was found to exist. Of course, there were cases which it was not possible to explain, but in the vast majority a general pattern began to make itself seen : this Soil Series gave consistently bad results with certain crops, while that one always produced fine and vigorous trees. Hundreds of growers had been amassing a vast store of information, for which they had paid dearly. But until it was possible to record the type of soil upon which their ventures had been made, that experience could not be applied as a guide for the future.

It has obviously not always been possible to place each fruit crop on the soil which suited it ideally. One began to be aware of the fact that each kind of fruit possessed a range of tolerance to adverse soil conditions. Some were very much easier to please than others. This is particularly clearly visible in the case of the drainage factor. Neither Leveller gooseberries nor cherries will put up with more than the slightest suspicion of poor drainage, whereas blackcurrants and pears show a remarkable degree of tolerance in this respect.

One must not, in emphasizing the importance of the soil as a factor in success, forget that skill in its management is even more important. Nevertheless, there is no gainsaying the fact that it is far easier, and generally far more profitable, to grow a crop upon a soil which suits it than upon one in which it is not really happy. Not only do adverse soil conditions lead to unsatisfactory growth and yield, but so often they lay the plant open to the threat of disease. Possibly the best example is the frequency with which Apple Canker asserts itself where the soil is poorly drained.

The assessment of soils.

When the behaviour of fruit crops had been studied in detail on a large range of Soil Series, certain generalizations began to appear. Soil Series which had certain characteristics in common began to show that they produced a like result in the crops planted on them. Thus, it seemed possible that wherever a particular characteristic was encountered in the soil, similar results might be expected. It is more than eighteen years since the Fruit Soil Survey was completed, so there has been ample opportunity for trying out this hypothesis in many parts of England. It is now possible to see that a number of the fruit plantations made as a result of these observations—and some contrary to advice given—have, in the main, done what was expected of them. It is thus possible to go into a completely new district and to form a fairly reliable assessment of its potentialities for growing fruit.

The process is simply one of making a mental comparison of the soils encountered there with those Soil Series whose performance is already known in detail. Thus, in examining a new soil with a view to deciding what crop should be planted upon it, one's observations can be divided roughly into four headings : the depth of soil ; the natural drainage ; the texture ; and the structure.

(i) **Depth.**

By depth of soil I mean the full depth of weathered material lying on top of what the geologist calls the " rock ". This includes both the topsoil and subsoil of the farmer. They are both part and parcel of the same thing and are as incapable of existing satisfactorily separated from one another as a head is detached from its body. In many cases the point at which the soil finishes and the underlying rock begins is fairly clear. There are times, however, when the transition is very gradual and it is difficult to determine an exact division.

Generalizations on a subject such as depth of soil are necessarily very dangerous, but I cannot help feeling that one must provide some datum by which to judge the endless variations. Any one will be able to quote numerous exceptions, but it would be safe to say that the depth of soil produced by the ordinary weathering *in situ* of the soft rocks of Britain is 16 to 18 inches. A rock which resists weathering may carry considerably less soil, or perhaps erosion may remove the soil almost as fast as it is formed. Soils shallower than average should be treated with considerable suspicion by the intending fruitgrower. As a whole, soils less than 12 to 14 inches should not be planted, except perhaps with the more vigorous types of crop where it would be inconvenient to leave an area unplanted.

One cannot consider depth of soil without taking into account the nature of the underlying rock. If this is easily penetrable by roots, then the depth of soil itself does not represent the whole extent of root-run. Roots may go deep in search of water provided they have air to breathe. In shallow soils one must consider carefully the water-holding capacity of the underlying rock. A loamy material like the Tunbridge Wells Sand or Thanet Sand will hold moisture well and will, to a certain extent, make up for shortcomings in soil depth but, as many a grower on an Essex " hot spot " will know, a coarse gravel may not.

Stone near the surface may give a false impression of shallowness of soil. Often the stone is much fissured with soil filling the crevices. Here the roots may penetrate quite deeply. The limestones of the Cotswolds afford such a case.

Many soils extend to a depth of several feet and, as a general rule, the deeper the soil the better it is. The majority of these deep soils are drifts, that is to say, they have not been produced by the weathering of the rock where it lies, but are accumulations of materials already weathered elsewhere, brought to their present position by rain washing, by rivers, blown there by the wind, or even carried by ice. They not only offer the plant a generous root-run, but their reservoir capacity for moisture is immense. At the same time, too, they offer a much larger realm in which to search for food. Consequently, the crops grow with great vigour upon them, and they should, as far as possible, be used for those which require such conditions.

(ii) **Drainage.**

For convenience, the short word of " drainage " is used to cover all the complexities of water movement in the soil. These include not only natural drainage and moisture retention but also the

supply of water from underground sources as well. To be of any use, a method for examining these characteristics must be independent of weather conditions. In fact, these points can be assessed at once from a boring made in the soil at any time. They involve a keen eye and a sensitive hand.

The well-drained soil is even coloured and free from mottle or " iron rust " stains. It is generally of a warm shade of brown or grey-brown. The poorly drained soil, on the other hand, is generally mottled in colour. If the poor drainage is slight, the mottling may be purely one of varying shades of brown. More severe waterlogging produces bluish-grey colours flecked with brown or orange-brown. Where the waterlogging is almost permanent the soil may be completely greyish-blue. The intensity of the symptoms depends to a certain extent upon the degree of poor drainage, but there are a number of other factors as well. Calcareous soils tend to mottle only slightly, while acid soils will often carry bright colour patterns. As well as the mottling, soils frequently contain deposits of iron oxide, which appear like small pieces of rust. These are known by various names, the commonest of which is " crowstone ". At times, especially when spring water brings iron from elsewhere, the crowstone and iron staining may be very intense.

In assessing the drainage condition of a soil, a factor of vital importance is the depth at which the symptoms make their first appearance. This represents the depth of well-drained soil in which roots can survive without danger of being drowned. One must bear clearly in mind with regard to this factor in particular, that seasons differ enormously in their effect upon the soil. When planning to plant perennial crops such as fruit, one must plan for the exceptional season and not for the average one, as for ordinary farm crops. It is folly to plant a cherry orchard on a soil which may waterlog once in ten years, only to see the trees wiped out in their dozens after an exceptionally wet winter. Yet this is a sight I have often beheld. This collapse of fruit trees in the spring, following a wet winter, is a sadly familiar phenomenon in many parts of the country, and is appropriately called " The Death ".

It is not enough to identify poor drainage. Its cause must also be ascertained.

(iii) Texture.

If you ask a farmer what his soil is like, the first thing he will almost certainly tell you is what its texture is, that is to say, whether it is light, medium or heavy. To him it is one of the most important factors because he has to work the land but, curiously enough, the majority of our crops are really remarkably indifferent. Nevertheless, certain of our fruit crops do show very distinct preferences. Texture is, in fact, a character which shows infinite variation. It is necessary, therefore, to devise a scale for the measurement of texture in much the same way that we have one for measuring length.

Numerous scales have been devised. Just as it is possible to sub-divide a yard into feet or inches, or even thousandths of an inch, so it is possible to sub-divide into endless grades of texture. The system generally accepted internationally recognizes twenty texture classes. For the layman, however, this is far too complicated. Nevertheless, some sort of yardstick is necessary, because when one goes into a district of clay land, the medium loam is referred to locally as " sand " ; equally, in a light district, the medium loam is referred to as " clay ". The competent grower should be able to make up his own mind exactly what the texture is without having to bow to local tradition. For him it is sufficient to be able to recognize five grades.

For this purpose the soil must be moist, although the experienced soil surveyor can recognize his textures tolerably well even though the soil be dry.

(*a*) *Sand.*—One can feel the sand grains easily and the soil so lacks finer material that it does not hold together on being moulded in the hand.

(*b*) *Light loam.*—Plenty of sand is still present, but the soil moulds quite well.

(*c*) *Medium loam.*—It is a smooth, soft soil practically free from palpable sand and easily moulded, but when pressed between the thumb and forefinger with a sliding motion it leaves a rough surface without any tendency to polish.

(*d*) *Heavy loam.*—The soil is sticky and when smeared between the thumb and forefinger leaves a slightly polished surface.

(*e*) *Clay.*—The soil is very sticky and when pressed out between the thumb and forefinger offers a certain amount of resistance, leaving a smoothly polished smear.

(iv) Structure.

All soils show structure to a more or less degree. At the surface the soil tends to break into a number of small crumbs, while deeper down these become larger and the blocks frequently tend to be shaped like rough columns or prisms. Thus, the soil in actual fact is not a solid mass but a three-dimensional jig-saw puzzle, the fragments themselves being porous. The importance of the structure cannot be overemphasized, because it is down the fissures that water and air penetrate most freely into the soil.

The soil pattern of almost every district is extremely complicated. When the individual soils are mapped, the result is often like a patchwork quilt. Good soils and bad lie side by side. This is what makes it so extremely important to plan most carefully when planting a crop which is designed to occupy the land for a long period. So often fruit trees will start most encouragingly but later fail to fulfil their initial promise. A few borings before planting might have prevented a disappointment—and financial loss. Just as there are poor soils in almost every fruit growing district, so there are many good soils outside the recognized fruit growing areas. These can be selected with confidence if the soil is examined thoroughly first.

The soil requirements of the various fruit crops.

It must be repeated that almost all kinds of fruit prefer a well-drained soil of adequate depth, but whereas some demand it, and if they cannot obtain it, fail, others will grow and crop quite satisfactorily on soils that fall far short of the ideal. It is thus perhaps worth while to summarize the soil requirements and soil tolerances of the chief kinds of fruit.

Cherries.—These must be placed first as they are amongst the most fastidious of crops. They must have good drainage and a medium-textured soil. If they are to produce fruit of really good quality, that soil must also be deep. The brickearth, in most places, complies with this specification, and it has come to be regarded as the typical cherry soil, although in actual fact there are numerous other soils on which cherries grow extremely well.

There are a few varieties which are more easily accommodated, but outstanding is Early Rivers, which will tolerate a certain amount of poor drainage and also a heavier soil than any other sort. This is convenient if one is faced with planting a block of which a part falls below the required standard. Noir de Guben is not far behind Early Rivers in this respect and fortunately they pollinate one another, although their picking season is not the same. At the other end of the scale is Napoleon Bigarreau, which is one of the most fastidious of all cherries. The sour cherries seem to do as well on sandier soils as they do on a medium loam, but to them also good drainage is very important.

Dessert apples.—Good drainage is an essential. But soils of medium depth, say, 18 to 24 inches, may be selected on all but the lightest land, as these are less liable to give excessive growth than the deeper drifts. The latter are perfectly satisfactory provided the management is modified accordingly. Apples show a remarkable indifference to texture : excellent fruit is grown on all manner of soils from the light sands of Suffolk to the heavy clays of the Sussex Weald.

Culinary apples.—Although these grow best on the deep, well-drained soils, they are nothing like so fastidious as dessert apples. Vigour of growth makes for heavy crops of large apples. Consequently, the deeper the soil the better, and it is no disadvantage if a small seepage of spring water in the lower layers keeps the subsoil moist. Culinary apples, and particularly Bramley's Seedling, will tolerate a wide range of soil conditions and put up with far worse drainage than dessert varieties. It is important when planning the orchard to assess carefully the growth potentialities of the soil before deciding on the planting distances.

Pears.—Pears are very catholic in their tastes for soil and are far less difficult to please than most kinds of fruit. They will put up with a quite severe degree of poor drainage, provided the soil water is not heavily charged with lime. Under such circumstances they are very prone to chlorosis. They flourish on a wide range of textures, but are particularly partial to heavy land. For the shallow clay soil such as one frequently encounters on the London Clay, there is no better fruit crop.

Plums.—These are best on a deep, well-drained soil, because vigour is necessary for the production of really large fruit. Thus, the selection of a good soil is important in the growing of dessert varieties. Nevertheless, plums, if adequately fed and well managed, are tolerant of quite a degree of poor drainage and will grow on a wide range of soil textures. As a whole, their soil requirements are somewhat similar to those of culinary apples.

Gooseberries.—Good drainage is of great importance to this crop, and especially so to Leveller, which will not put up with the slightest wetness. Careless, on the other hand, is a variety which is far more tolerant in this respect. The size of fruit is dependent to a considerable extent upon the moisture available, and consequently depth of soil becomes an important factor.

Blackcurrants.—Of all fruit crops, these are able to withstand poor drainage better than any. Nevertheless, it must not be imagined that they prefer such conditions. Heavy manuring does, however, seem to compensate for many of the shortcomings which the soil may exhibit. As a whole, blackcurrants prefer the medium and lighter types of soil to the heavy ones, although Wellington XXX and Westwick Choice are sound varieties for the heavier land.

Raspberries.—Good drainage is important but also a good moisture supply is essential if the crop is to be heavy. Consequently, a deep soil is desirable.

Loganberries and blackberries.—These are not difficult to suit as to soil but, if they are not to escape frost damage to their canes, one should be selected which does not encourage autumn growth. Thus, soils moistened by spring water should be avoided.

Strawberries.—Strawberries (if I may be permitted to mention them, as my title refers to the fruit tree) are able to withstand a considerable degree of poor drainage, but they like a soil which retains moisture well, so that adequate depth is essential. They do well on the light loams of the High Weald, but also produce a fine quality fruit on the heavier soils of the Clay-with-Flints.

In planning out the planting of different kinds of fruit, it is essential to arrange those which it is desired to grow in a list of priority. Those which are particularly fastidious should be accommodated first, leaving the more tolerant ones to be fitted in the gaps.

The management of soils.

Although the soil is the most indispensable of all the raw materials man handles, it is different from the others in several respects. It can be used over and over again without diminishing ; it should, in fact, improve. Its response to the skill with which it is handled is more subtle and more versatile than that of others. The soil is not a dead, inert mineral ; it is a most complex organization which is in a constant state of change and variability. Not only do its moisture, temperature and atmosphere change almost hourly, but it alters in the amount and composition of organic matter and in its inorganic chemical compounds too. It changes more gradually in structure, in porosity and compactness.

But besides all this, it is the home of the roots not only of our crops, but of the weeds which compete with them, or the cover crops we grow under them. It is filled with lower plants as well, including fungi and algae. It is the whole universe to a teeming population of insects, earthworms, protozoa and bacteria. All these have their own lives to lead and their own work to carry out. But they are all subject to two great outside influences : man and the weather.

Over and over again, soil surveys have shown that man's management is the over-riding factor in almost every soil. To talk of " good soil " or " bad soil " can be very misleading. Every soil has a range of performance. Under bad farming it may produce scarcely anything. I have often seen complete crop failure on a brickearth which would have been capable of carrying a first-class cherry orchard. Properly managed, every soil can be cropped, but each has an upper limit beyond which it cannot go, or perhaps beyond which it is not economic to attempt to take it. The same is true of human beings : one can train any gathering of human beings in a particular accomplishment, be it playing lawn tennis or speaking French. Soon they will begin to separate out, some showing promise and others very little. Nevertheless, with perseverance all will improve, but in widely varying degrees. Soils are improvable in precisely the same way. It obviously pays best to plant on the most promising soils and to avoid, as far as possible, the others. It does not mean, however, that upon the less promising soils nothing is possible. Perfection, even in soil, is seldom attainable. The majority fulfil their responsibilities with varying degrees of efficiency.

The function of the examination of soils in the field is to discover their potentialities and decide on the means necessary for their full attainment. By examination of the soil in the field, and by that means alone, can it be decided whether it is suitable for cherries or dessert apples, or whatever other crop. No amount of analyses will give that information. They are an essential guide to the manuring and treatment of the soil, but the initial decision must rest upon the verdict of the soil auger and of the man using it.

The land may have to be drained before it can be planted. But how often do we see the foolhardy experiment of draining the land without its first being soil surveyed ? Draining is an expensive operation and in many cases I fear that the land after piping will not be worth the money spent. Yet at other times a soil lies almost derelict for want of a few pipes that could make it first-class. A few weeks ago I saw a scheme approved for draining a fruit plantation at a cost of more than £300. Water stood a foot below the surface, yet at 3 feet there was a layer of gravel. All that was needed was a short length of ditch to be cleaned to expose the seam of gravel. Nature had provided a perfect drain, yet man, in his ignorance, was preparing to instal a redundant one at a cost of hundreds of pounds.

The depth and spacing of pipes must all depend upon the nature of the soil. A major operation should be preceded by a careful diagnosis. In fact, no drainage scheme ought to be certified for grant until this preliminary has been carried out. The golden rule is to drain deep soils deeply and shallow soils shallow. It is no good putting pipes part way down a deep soil, and wasting half this precious gift that nature has taken centuries to produce.

Often the auger will reveal a magnificent soil, yet the crops proclaim their disagreement. Analyses may have shown that the few plant foods we can express in figures are there, and there in plenty. The

soil surveyor may even have to bear the grower's scepticism. It must be remembered though that the soil is more than a mixture of chemical compounds, and that it should contain organic matter as well. So often the cause may be sought in the near absence of the latter. While I do not subscribe to the various schools that endow humus with mystical properties, I do confer upon it a very important place in the maintenance of soil fertility.

It is for that reason that I welcome the rapid extension of cover cropping in fruit. By mowing or grazing grassland, or ploughing in green crops, we return great quantities of organic matter to the soil. This encourages the multiplication of earthworms and soil fungi, both of which have a vital part to play in building up the structure of the soil. It is upon this structure that the free ingress of air and water depends, and also the free movement of roots. Air, water, and roots share the complicated communications system of the soil. This can be likened to our own network of roadways. Earthworms, which penetrate a number of feet into the ground, construct the arterial roads. The soil itself, as I have already said, is divided by a number of fissures, which correspond to the secondary roads ; the individual blocks of soil are traversed by minute holes left by the decay of roots : these are the country lanes. It is upon the development of this system, which in itself is dependent largely upon the amount of decaying organic matter, that the full efficiency of the soil depends. Earthworms, too, with their penetrating shafts, tend to deepen the soil, pulling down organic matter even well into the unweathered geological material beneath the soil.

Only if the management favours them can this work proceed. The farming out of land is as often due to loss of structure as it is to shortage of plant foods, and it is waste of effort and money to lavish fertilizers on soil that has thus deteriorated. So often the structure of the soil is destroyed by cultivation. The wheels of our tractors, running in the furrow, compress the soil beneath the layer of cultivation and leave a compact impenetrable pan. So effectively is the air shut out that the soil shows the same symptoms as are produced by waterlogging.

In planning any scheme of planting, it is vital to realize that the soil has a third dimension. One cannot escape taking the soil into account because we now realize that the different kinds of fruit show their preferences, and so also do the different varieties. We begin even to find that individual rootstocks show quite marked soil responses. Then, too, there is the matter of planting distances. All these points must be considered in detail, as far as our information allows.

The grower cannot fail to benefit from a fuller understanding of his land. So often, too, the research worker neglects to take the soil into account. So much work is carried out on the assumption, patently false, that all soils are alike. This has brought many a valuable piece of work into discredit. As far as possible, the soil upon which the experiment is carried out should be described in detail, so that its applicability to other areas can be determined.

There is a pressing need for more soil survey work and for the correlation of crops with the soils identified. The introduction of new varieties and new methods makes this work perpetual. There is still much unanswered about the soil, but I submit that we have made a beginning, and that we are advancing along a road which holds out promise of rich reward.

Fig. 1.
Royal Sovereign showing variant crown on left and normal crown on right.

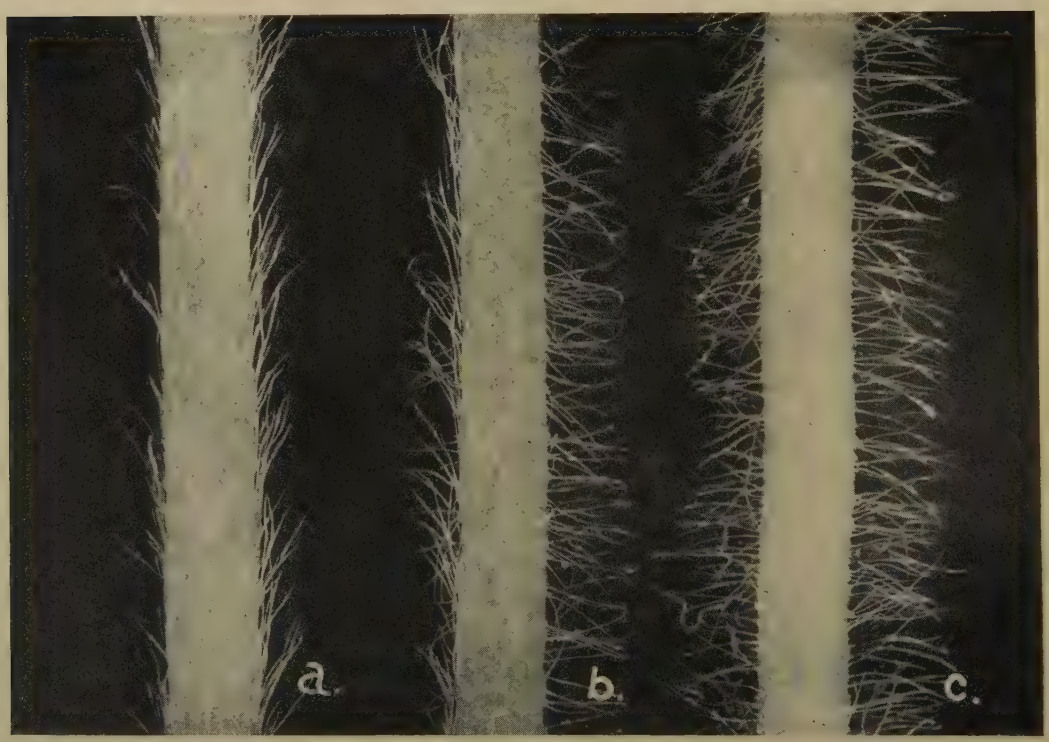

Fig. 2.
Leaf stalks from one chimeral plant, showing (*a*) upward hairs (*b*) half upward and half outward and (*c*) normal outward hairs (×5 approx.).

[*face p. 61*

POMOLOGY

A BUD-SPORT IN ROYAL SOVEREIGN STRAWBERRY*

By W. S. ROGERS

In July, 1949, Mr. J. E. Spickernell, Provincial Fruit Specialist, East Midlands, found some variant plants in a stock of Royal Sovereign M.40. A study of sister plants at this Research Station has established that the variant must have arisen as a bud-sport or mutation, probably in only one crown of one plant, and been multiplied by runners.

The variant resembles Royal Sovereign in every recognizable character except that the hairs on its leaf stalks go upwards (as in the variety Pillnitz) instead of outwards. In a runner bed of 757 plants at the Research Station, 7·5 per cent. were of this variant form, and 1·1 per cent. had both normal and variant crowns (Fig. 1). In two plants some leaves with outward hairs on one side of the leaf stalk and upward ones on the other were found (Fig. 2), and in another, two consecutive runner-plants on a single stolon had upward and outward hairs respectively. These facts prove that the mutation occurred as a chimera, i.e., two different tissues growing in the same plant. This is a well-known phenomenon in several horticultural plants, for instance, the variegated Pelargonium and the Thornless Loganberry ; but this is the first proved case, so far as the author is aware, of its occurring in the strawberry.†

In the Thornless Loganberry the changed thornless tissue covers the whole skin of the plant, and any buds arising from it are thornless ; but buds arising from internal tissues, such as suckers from the root, produce thorned shoots. This is called a periclinal chimera (Fig. 3 (*a*)).

The present case is different, in that only a sector of tissue appears to have been affected. This is shown diagrammatically in Fig. 3 (*b*) and (*c*). Stolons arising from the " normal " portion (N) produce

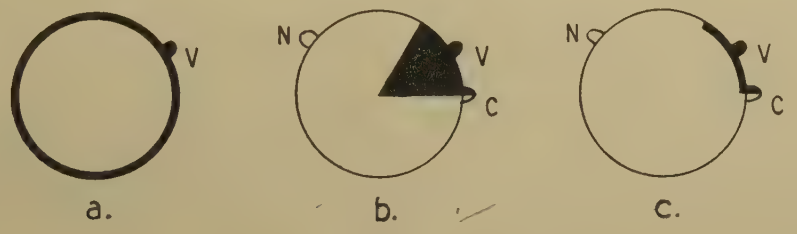

Fig. 3.

Cross sections of chimeras (*a*) periclinal (*b*) sectorial and (*c*) mericlinal ; (C) chimeral bud (N) normal bud and (V) variant bud. (After Crane and Lawrence, "The Genetics of Garden Plants ".)

plants normal in every respect. Those arising from the variant portion (V) produce plants with only variant (upward) leaf stalk hairs, and a few stolons arising at the junction of the two different tissues produce plants which continue as chimeras, with more or less of the variant tissue in them, according to the chance position of the bud.

It is not yet proved if the chimera is " sectorial ", as in Fig. 3 (*b*) or " mericlinal " as it is called if part of the outside tissue only is changed (Fig. 3 (*c*)). Both can produce normal, entirely variant and mixed plants.

There was no significant correlation between number of variant plants and crop weight of fruiting plots containing differing numbers of variant plants. It is, therefore, unlikely that the variant is of much commercial importance. From the point of view of Certification Schemes, however, it is very desirable to eliminate the variant from stocks used for runner raising, as stocks containing mixed plants cannot be certified as " true to type ". Evidence so far suggests that the variant is confined to certain stocks sent from the Research Station in 1947 and 1948. Growers who have received such

* Slightly different versions of this paper appeared in *The Grower*, 1949, **32**, 413-4, and *The Fruit-Grower*, 1949, **108**, 403.

† A note by G. M. Darrow (*J. Heredity*, **17**, 404, 1926), on a change in fruit stalk length, possibly due to mutation, is the only previous report that has come to the writer's notice.

stocks would be well advised to inspect them closely and remove any variant plants, or else to use such runners only for fruiting and not for further propagation. In looking for variants it should be remembered that the hairs on *stolons* of *normal* plants are adpressed upwards ; and hairs on very old leaf stalks can stand in all directions.

The chimeral plants themselves are, of course, of scientific interest, and stocks will be raised for experimental purposes.

Acknowledgements.

I wish to thank Mr. J. E. Spickernell, Mr. M. B. Crane, Miss D. J. Wilson and Miss J. M. Buttfield for helpful information.

Summary.

A bud-sport in the Royal Sovereign strawberry is described and illustrated.

LOW TEMPERATURE INJURY TO FRUIT BLOSSOM

III. WATER SPRINKLING AS AN ANTI-FROST MEASURE

By W. S. ROGERS and IRENA MODLIBOWSKA

Sprinkling plants with water during frost has long been recognized as a possible protective measure, but there has been much difference of opinion as to its value and practicability, and very little experimental evidence on which to base conclusions.

The protective effect depends on the transfer of heat from the added water, partly as it cools to the freezing point, releasing one calorie per gramme per degree C. fall, but mainly by the release of the latent heat of freezing of the water as it is turned to ice. This, approximately 80 calories per gramme of water frozen, is equal to about 1,440,000 B.Th.U. per 1,000 gallons.

West and Edlefsen (1917) were unsuccessful with spraying an apricot tree in full blossom during a frost. All flowers on which ice had formed were killed, whereas flowers on adjacent unsprayed trees were undamaged.

Mercanton (1939) reports a successful experiment by Professor J. Gattlen in the Haut-Valais in Switzerland. Gattlen sprinkled small fruit trees, dahlias and vegetables continuously while temperature remained below 0° C. There was no visible damage and good crops were produced, although the air temperature fell to −6° C. (21·2° F.).

Kessler and Kaempfert (1940), in several experiments at Trier, succeeded in protecting strawberries, tomatoes and potatoes with artificial rain during frost. Unfortunately their work was not carried further.

Laboratory trials.

A preliminary trial in the new frost laboratory at East Malling in May, 1948, consisted of dropping cold water on to an apple blossom (variety Ellison's Orange) while the air temperature was reduced to −3·0° C. (26·4° F.). Continuous " sprinkling " at the rate of about one drop per three seconds kept the flower temperature close to 0° C. The flower was encased in ice and no damage was visible after thawing. Temperature measurements were made, using 40 S.W.G. copper-constantan thermocouples, inserted in the ovaries of the sprinkled and unsprinkled flowers. The fine wire thermocouples were soldered to stronger copper and constantan leads of 28 S.W.G. Air temperature was measured with 28 S.W.G. thermocouples. A special potentiometer, calibrated to read direct in tenths of a degree centigrade, was used.

Fig. 1 shows the temperature records of this experiment. It can be seen that the dry flower followed the air temperature at first, and supercooled* to −2·5° C. (27·5° F.). It then froze, as shown by the sharp rise of its temperature to −1·5° C. (29·3° F.) in ten minutes, due to the release of latent heat by ice formation within its own tissues. Freezing continued slowly for a further thirty-five minutes, during which its temperature was still above that of the air. Warming up of the air had by then been started. The frozen flower remained cooler than the air for forty minutes during the melting of the ice within its tissue.

The sprinkled flower also supercooled for the same length of time, but only to −1·1° C. (30·0° F.), before the water upon it began freezing. Its temperature then rose sharply and remained at from −0·1 to −0·3° C. (31·5 F.) (Fig. 1). When warming up of the air began, the temperature of the sprinkled flower gradually rose to 0° C., and remained there until its ice was melted.

Thus this experiment demonstrated not only the warming effects of continuously added water, but three other important features, i.e. supercooling before freezing, release of latent heat of freezing, and delay of temperature rise in frozen material during thawing due to absorption of heat by the melting ice.

In a later experiment of this series, sprinkling was stopped before thawing began, and it was found that the temperature of the wet flower then fell rapidly and the flower was killed. Doubtless the presence of ice on the surface facilitated " inoculation " of the tissue.

In both experiments unsprayed control blossoms were killed.

* i.e. temperature fell to below its freezing point, but without formation of ice.

Field trials.

A trial of sprinkling small apple trees in the open was carried out on the nights of 7th-8th and 9th-10th May, 1949, in the large Bradbourne walled garden.

Material and methods.

The trees were of the varieties Fortune, Wagener, Ribston Pippin and Sunset, grown as dwarf pyramids on M.IX rootstock. They were four years old, about 3 ft. to 4 ft. 6 in. high, and planted at

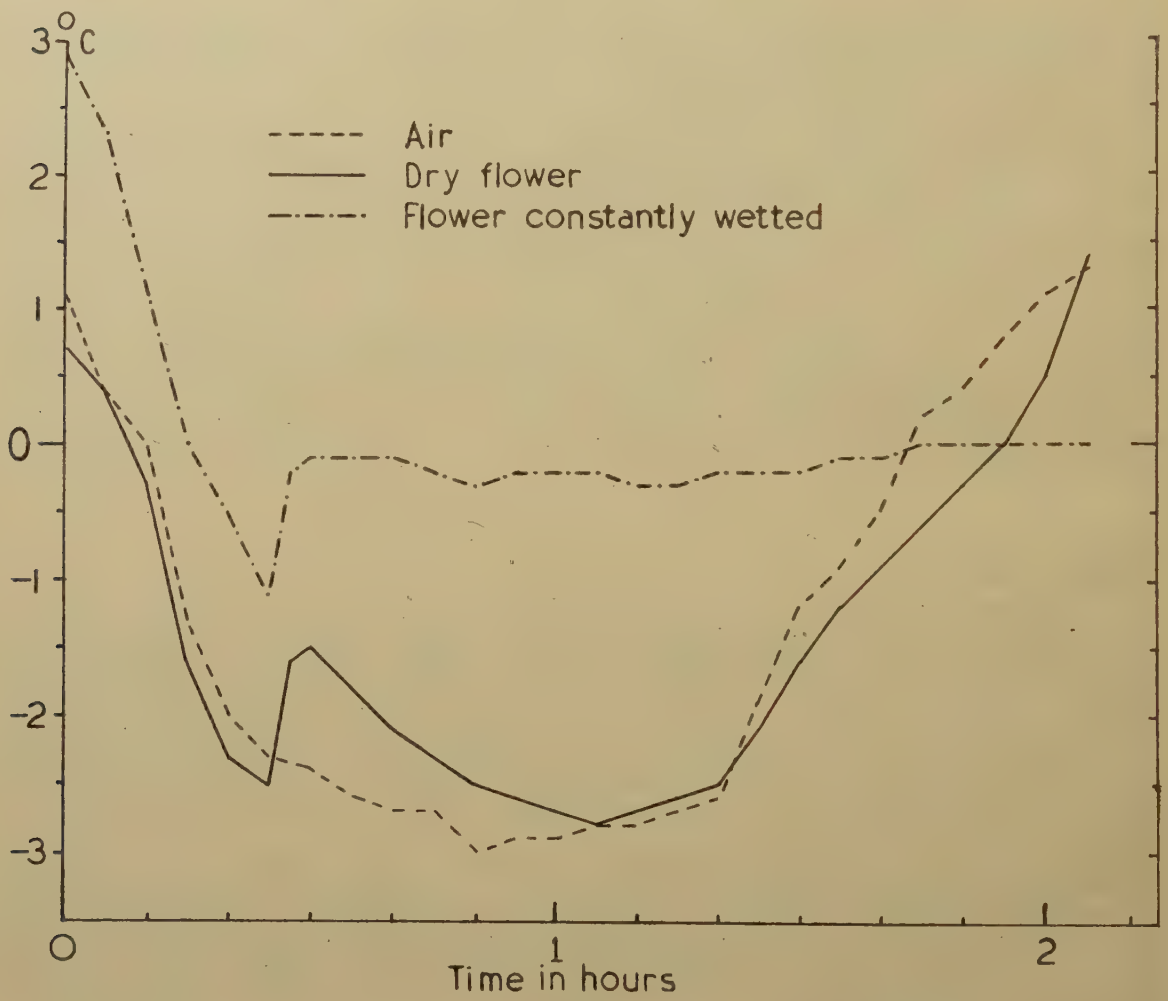

FIG. 1.

Effect of water sprinkling on temperature of apple flower during exposure to low temperature in the laboratory.

3 ft. spacing in rows 6 ft. 6 in. apart. The varieties formed blocks of six rows of six trees, in the order : Sunset, Fortune, Wagener, Ribston.

All the varieties were blossoming profusely. At the time of the experiment Fortune had just passed full bloom, Sunset and Ribston were still flowering, and Wagener was almost over.

The ground was covered with a grass and clover sward, about 2-3 in. high, with narrow cultivated strips 21 in. wide along the tree rows.

Two 15 ft. lengths of Kinnell oscillating spray line having jets approximately 0·8 mm. diam. 2 ft. apart, were installed at the junction of the Fortune and Wagener blocks, at a height of 2 ft. 9 in. The sprays covered five rows, and extended further to the North than to the South, including thirty trees of Fortune, thirty Wagener, twenty Ribston and ten Sunset trees. The adjacent unsprayed trees were used as controls.

Six rain gauges (10 cm. in diameter) were distributed over the area, to measure the precipitation at 6, 15 and 24 ft. from the spray line, on both sides.

Two exposed bulb Meteorological Office type minimum thermometers were hung at a height of about 2 ft. 9 in., one in the sprinkled area and the other outside it.

Two soil thermometers were installed at a depth of 4 in. in the middle of the narrow cultivated strips along the tree rows, one in and one outside the sprinkled area.

Within the watered area, one thermocouple was placed in the ovary of an open Fortune flower at a height of about 2 ft. 6 in. and one (unscreened) in the air adjacent to it. Two thermocouples were placed in similar positions outside the watered area.

A trailer caravan 40 yards away housed the potentiometer with which the temperatures were recorded.

The Frost of 7th-8th May.

The main experiment was done on 7th-8th May, when a typical radiation frost of long duration, but not of great severity, giving a screen minimum of −1·7° C. (28·9° F.), was experienced.

At 10.40 p.m.* the sky was quite clear and the air calm. Grass temperature was then 0° C. and screen temperature +2·8° C. (37·0° F.). Dew was starting to form on the lower exposed leaves of the apple trees ; it was not yet obvious, but could be felt by passing the finger over a leaf surface.

At 11.40 p.m. grass temperature was −1·1° C. (30·0° F.), and screen temperature +1·1° C. (34° F.). Hoar frost was visible on the sward, especially on the clover and broad-leaved weeds, but none was visible on apple leaves. The flowers were at 0° C., and covered by a light dew. No dew had yet formed on the tree trunks.

At 12 midnight, dew was abundant, even on the flower petals, but no hoar frost was yet visible on the trees. At 12.10 a.m. grass temperature was −1·1° C. (30·0° F.), and screen temperature +0·6°C. (33·0° F.).

Temperature readings, as shown by the thermocouples, were taken from 10.45 p.m. to 7.45 a.m. the following morning. After 11.45 p.m. they were taken every five minutes.

It can be seen that the air temperature fluctuated considerably from reading to reading (Fig. 2). This is normally found when very sensitive thermometers are used, though such fluctuations are not shown by less sensitive bimetallic thermographs. The temperature fell slowly at an average rate of only 0·7° C. per hour, and reached the minimum of −2·1° C. (28·2° F.) at 3.30 a.m. It then rose slightly, and again fell to −2·1° C. at 5.20 and 5.30 a.m. ; from this time it rose at the rate of 2·2° C. per hour. During warming up there was a pause of ten minutes at 0° C., presumably due to the melting of ice.

The unsprayed flower followed the air temperature fluctuations closely at first, and the exact moment when it began to freeze is not easy to see, for it is probably masked by the air temperature fluctuations.

Inspection of Fig. 2 suggests, however, that the main period of ice formation within the flower was from 2.15 to 3.30 a.m., during which time the air temperature fell from −0·7° C. (30·7° F.) to −2·1° C. (28·2° F.), and the flower remained at a higher temperature, from −0·5° C. (31·1° F.) to −1·6° C. (29·1° F.). The fact that the flower temperature fluctuated much less than that of the air during this period and the subsequent two hours also suggests that ice formation was taking place continuously for about three hours. The minimum temperature inside the flower, −2·2° C. (28° F.) was reached at 5.25 a.m., five minutes before the official time of sunrise, and twenty-five minutes before the sun rose over the garden wall. The rate of temperature fall in the flower during freezing (i.e. until the flower temperature fell to that of the air) was 0·9° C. per hour, while the rate of warming up was 2° C. per hour, 0·2° C. slower than that of the air, due to thawing of ice in the tissue.

Sprinkling.—The sprinkler was turned on at 12.55 a.m. when the air temperature had fallen to −0·8° C. (30·5° F.) and flower temperatures were 0·2° C. to 0·6° C. lower, owing to radiation. Sprinkling continued for about six hours during which time about 1,000 gallons were applied, equivalent to about 3,750 gallons per acre per hour. The precipitation decreased markedly from the region 6 ft. from the spray line to the outer extremities of the sprayed area. Gauges placed 6 ft. from the spray line collected 8·5 and 8·6 mm. of water per hour, those at 15 ft., 2·3 and 4·7 mm., and those 24 ft. away, only 0·2 and 0·7 mm. The average precipitation was thus approximately 4·2 mm. per hour, and the mean total over the whole area 25·2 mm. or 1·0 in. for the six hours.

The water temperature at the sprinkler was +8° C. (46·4° F.), and the sprinkler oscillated fifteen times per minute. Sprinkling was continued until the air temperature had risen to 0° C.

Results.—When the sprinkler was turned on, the temperature of the sprayed flower, which had previously followed that of the air, rose to and remained at between 0° C. and −0·6° C. (30·9° F.) (Fig. 2). Some of the water dripped off the sprinkled flowers, and some froze on them. At 4 a.m. most

* Times are in British Summer Time, one hour in advance of G.M.T.

of the leaves and flowers on sprinkled trees were covered with a 1·5 mm. layer of ice, and icicles 1 to 2 cm. long were hanging from the leaf tips and the wires which supported the trees (Figs. 3 and 4). Young shoots and leaves of sprinkled trees were rigid, while those of unsprinkled trees drooped with a wilting appearance, although they too were frozen stiff (Fig. 5).

During thawing, the temperature of the sprayed flower remained at 0° C. until no more ice was present on the ovary. Then while ice still remained on the petals and around the styles, the temperature of the ovary rose to +0·5° C. (32·9° F.) as the air reached +2·1° C. (35·8° F.).

Subsequent examination of the blossoms, in which thermocouples had been inserted, showed their reaction to have been similar to that of the other sprinkled and unsprinkled blossoms. The sprinkled flower suffered no visible frost damage, not even loosening of the skin (which includes the epidermis

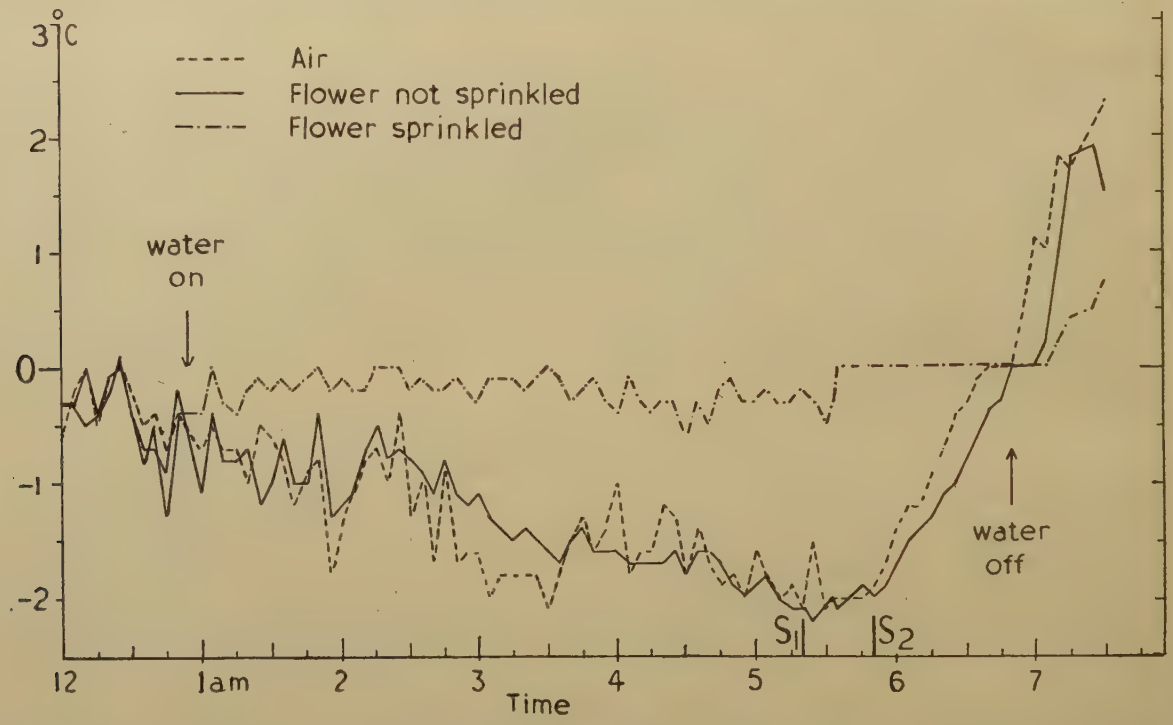

FIG. 2.

Effect of water sprinkling on temperature of apple flower during a frost in the orchard. S.1.—official time of sunrise S.2—time of incidence of sun's rays in the orchard.

and some or all of the hypodermal layers) and no symptoms of internal ice formation were found. The unsprinkled flower, however, froze and was killed. It showed complete loosening of the skin and brown discoloration in styles and ovules. A record was made of frost damage on the exposed open flowers of the variety Fortune, on 9th May, by which time any damage would be visible. The numbers of flowers examined and the percentages killed, as shown by browning of the styles, were as follows :

	Sprinkled.	*Unsprinkled.*
Numbers of flowers examined	187	152
Percentage killed	3·7	26·6

While the frost damage was not very severe, as the air temperature at the level of the flowers only fell to −2·2° C. (28·0° F.) the contrast between sprinkled and unsprinkled blossoms is very marked. The small amount of damage on the sprinkled trees may have occurred on 1st May, when a screen minimum of −1·2° C. (29·8° F.) was recorded.

The Frost of 9th-10th May.

On 9th May a frost warning was received late in the evening, and the screen temperature fell to below freezing from 4.20 a.m. to 5.45 a.m. on the tenth. A screen minimum of −1·2° C. (29·8° F.) was recorded. The sprinkler was turned on from 4.20 to 6.00 a.m., and 5·7 mm. of water was applied.

No bud temperatures were taken on this occasion, but the Meteorological Office glass thermometer in the sprinkled area indicated a temperature of —0·3° C. (31·5° F.) during the time that water was freezing on its bulb, showing that the blossoms on which water was freezing, in the same area, were probably also behaving in the same way as on the night of 7th-8th May.

The subsequent records of fruitlet damage and final yield are, of course, the combined results of the two frosts and sprinklings.

Results.—Samples of 100 fruitlets of Wagener were removed, cut and examined on 14th May. The following percentages were found to be killed, as shown by blackened ovules.

Sprinkled.	*Unsprinkled.*
18·8%	45·0%

The contrast is again marked.

As already remarked, the damage to the sprinkled fruitlets may have occurred previously.

The amount of frost damage was not enough to prevent the setting of a good crop, and actually all these young trees cropped well for their size. The sprinkled trees did in fact produce from 25 per cent. to over 100 per cent. more fruit than the unsprinkled ones ; but as there was considerable variation between trees in previous years, it cannot be stated whether the differences are due to the sprinkling, to the irrigation of the soil, or to other factors.

Subsidiary effects of sprinkling.

The sprinkling had an appreciable effect on the soil temperature. It was found that the sprinkled soil at a depth of 4 in. was about 1° C. cooler than the unsprinkled soil, in the morning following the water application. During the day the unsprinkled soil temperature rose to +17·5° C. (63·5° F.), and the sprinkled soil was then 2° C. cooler. For about a week the wetter soil remained about 0·5° C. cooler than the drier soil. Two main reasons for this are that the wetter soil would, for a period, have a higher evaporation rate during the day, thus having a cooling effect ; and that the wetter soil would have a greater heat conductivity, so allowing greater loss of heat during the night—a feature which would itself have a small protective effect against frost.

The sprinkling also had a beneficial effect as irrigation. During the night of 7th-8th May, 25·2 mm. of water was applied, and on the night of 9th-10th May, 5·7 mm. making a total of 30·9 mm. (1·2 in.) of water. The total natural rainfall for May, June and July was as follows :

	May.	*June.*	*July.*
1949	2·14 in.	0·58 in.	0·54 in.
30 year average ..	1·77 in.	1·44 in.	2·20 in.
Difference	0·37 in.	—0·86 in.	—1·76 in.

Thus although May was fairly moist, June and July were very dry. It was observed on 4th July that the cover crop, particularly the clover, grew more thickly and vigorously on the sprinkled than on the unsprinkled plot, but the grass eventually turned brown in both areas. The trees on the sprinkled plot also appeared to grow more vigorously.

Discussion.

These preliminary experiments have shown clearly that continuous sprinkling of blossoming fruit trees with water during a spring frost can protect the flowers from freezing. Damage was prevented in air temperatures as low as —3° C. (26·6° F.) in these experiments, and in those of Kessler and Kaempfert down to —7° C. (19·4° F.).

Formation of ice on flowers and leaves as a result of six hours sprinkling with an application of 25·2 mm. (1 in.) of water did not cause any mechanical damage to flowers or other parts of the tree.

As already stated, water sprinkling protects the blossoms by warming them, but it should be appreciated that the heat liberated during freezing is absorbed again during thawing. Thus, in effect, the cooling is transferred from the frosty night, when it is dangerous, to the warmer day, when it is harmless.

The method seems particularly suited to trees in grass or cover crops, for such swards prevent damage to the soil by the rather heavy rainfall produced by the forms of sprinkling apparatus at present commonly available. Ground covered with winter weeds would probably stand a limited amount of sprinkling. Newly cultivated soil might become sodden and puddled under such applications.

The amount of water which would release enough heat to counteract a normal spring frost is much smaller than that applied in the field experiment described here. The freezing of only 750 gallons of water would liberate about 1,000,000 B.Th.U., which it is calculated would replace the heat lost per

acre per hour in a radiation frost. The water must be applied in such a way that the temperature of the flower does not fall to the freezing point of the cell sap. Thus a single wetting would not protect the flower for long. On the other hand, absolutely continuous sprinkling is not necessary. The safe interval will depend mainly on the air temperature and the thickness of ice on the blossoms. Experiments are now in progress to determine the longest safe intervals under varying conditions.

It is fortunate that the two factors severity of frost and thickness of ice will normally tend to counterbalance to some extent ; for while, with increasing duration of frost, the air temperature commonly gets lower, so at the same time the ice layer on sprinkled blossoms will get thicker.

Advantages of water sprinkling as a frost control measure are that, once the apparatus is installed, labour costs are low. In fact, automatic starting and stopping of the apparatus according to the air temperature would be possible. Sprinkling can also, within limits, give protection from wind frosts in which most other protective devices are of little use.

Disadvantages are the high capital cost, and the large amount of water required. For normal irrigation, portable apparatus can be used on different fields in succession ; but for frost control, the whole area concerned must be sprayed at the same time.

At present, therefore, sprinkling as a frost prevention measure appears practicable only (1) in areas where overhead irrigation is already installed for other purposes, (2) in gardens, and (3) on a limited field scale in places where large supplies of water are readily available.

Before sprinkling with water as a frost prevention method can be generally recommended, methods of applying small quantities of water continuously at a fairly low capital cost will have to be devised. Detailed studies will be necessary of the best amounts of water for different conditions of climate and tree, the best times of beginning and ending the sprinkling and the best forms and methods of sprinkling. These will require both intensive laboratory and field investigations. Further experiments are in progress.

Acknowledgements.

The writers acknowledge with thanks the valuable help of Mr. J. Thorsrud in the 1948 experiments, and of Miss N. Wallick and Mr. C. H. W. Slater in those of 1949.

Summary.

1. Preliminary laboratory and field experiments, including measurements of temperature within flowers, have shown that continuous sprinkling of fruit tree blossoms with water during spring frosts can protect them from freezing.

2. Formation of ice on flowers and leaves as a result of six hours sprinkling with an application of 25·2 mm. (1 in.) of water in an air temperature falling to —2·2° C. (28·0° F.) did not result in any mechanical damage to flowers or other parts of the tree.

3. Sprinkling cooled the soil by 1° C. to 2° C. at 4 in. deep. No harmful effects were found, in a grass orchard, and in fact the effects appeared beneficial.

4. The use of existing overhead irrigation apparatus, as a frost control measure on a limited scale, appears practicable. Fully automatic control is possible. Before the method can be recommended on a large scale, however, further study is needed, and new apparatus will possibly have to be devised. Even if more economical methods of application can be found, large supplies of water would be required.

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Fig. 3.

Icicles formed by sprinkling during freezing, May 7th-8th, 1949. Photo taken 5.30 a.m.

[face p. 68

FIG. 4.
Flower cluster and leaves encased in ice. Note turgidity of leaves.

FIG. 5.
Wilting appearance of unsprayed shoots during freezing. 5.30 a.m., May 8th, 1949.

NOTES ON FROST DAMAGE SYMPTOMS ON FRUITS IN 1949

By IRENA MODLIBOWSKA and ELIZABETH M. GLENN

Although no very severe frosts occurred at East Malling in May, 1949, the following minimum temperatures were recorded in the screen, between 1st and 10th May : 31° F. on the morning of the 1st, and 29° F. on the mornings of the 8th and 10th (see Diagram page 80). At this time, cherries and plums were at the cot split stage ; pears were developing small fruitlets ; most apples were dropping their petals, although Crawley Beauty was still in bud ; most walnuts had just begun flowering ; raspberries were still in the early green bud stage ; strawberries had just begun flowering ; and black currants had already finished flowering. Under these conditions few fruits were very seriously damaged, and most set good crops ; but a number of typical symptoms of frost damage were visible on the fruits.

Top Fruits.—Apples.

Some frost damage was noted on blossoms and young fruitlets of many varieties. In general, the later flowering varieties were less damaged, with the exception of Court Pendu Plat, which was quite badly affected.

The blemishes on mature fruits mostly took the form of " frost eyes ", " frost rings " or " green blotches ".

Frost eyes were commonly found on fruits of Bramley's Seedling and Lane's Prince Albert.

Frost rings occurred chiefly on James Grieve (Fig. 1) and to some extent on Sunset, Wagener and Fortune. On Worcester the ring sometimes consisted of a constriction only, without any russeting.

Green blotches occurred on Ellison's Orange, and occasionally also on other varieties. Some fruits showed development from green blotch, by russeting and cracking, to frost eye (e.g. Orleans Reinette, Fig. 2, C, Crawley Beauty, Court Pendu Plat) or to frost ring (e.g. Ellison's Orange, Fig. 2, D).

The variety Edward VII had some fruits with russet patches round the eye, or russet lines running from stem to eye (Fig. 2, B, A).

Some varieties, e.g. Sunset, became russeted towards the stalk and later cracked, producing poor quality fruit. It was difficult to determine how much of this was due to frost, and how much to other factors, but it is probable that the low temperatures were partly responsible.

It has been stated that frost eyes are formed as a result of damage at an early stage of floral development, and frost rings as a result of damage at a later stage (see Bush, " Frost and the Fruit-grower ", p. 64). Observations made in 1949 do not entirely support this theory. Some varieties at the same stage of floral development showed frost blemishes on different parts of the fruit (e.g. Worcester Pearmain and Bramley's Seedling), while some at different stages at the time of frost showed similar damage (e.g. Lane's Prince Albert and Bramley's Seedling). It appears that the position and type of blemish is primarily a varietal characteristic, as will be apparent from the accompanying Table I, although the stage of development of the flower at the time of frost may also play some part.

TABLE I.

RELATION OF FROST DAMAGE TO STAGE OF DEVELOPMENT.

Variety.	Stage of development.	Position and type of damage.
Crawley Beauty	green cluster	frost eye and green blotch
Court Pendu Plat	pink bud	frost eye and green blotch
Edward VII	pink bud	russet patches in a ring
Lane's Prince Albert	open flower	frost eye
Sunset	petal fall	frost ring and green blotch
Worcester Pearmain	petal fall	frost ring
James Grieve	petal fall	frost ring
Ellison's Orange	petal fall	frost ring and green blotch
Bramley's Seedling	petal fall	frost eye
Early Victoria	petal fall	frost ring

Pears.

Damage was very variable from plot to plot, and it is difficult to say which varieties were most susceptible, except that Durondeau was consistently more damaged than other varieties.

Numerous short, and often deep, radial cracks or russet lines were present on some mature fruits, particularly on Williams' Bon Chrétien and Glou Morceau. The cracks were visible by mid-May, but became more pronounced as the fruits developed (Fig. 4, B).

Quinces.

Many kinds of blemishes were seen on quince fruits (Fig. 4, A), such as russet eyes and vertical rows of short horizontal cracks. Some fruits showed irregular patches of small cracks, either around the eye or near the stalk, usually between the carpels.

Cherries.

Frost damage to the fruitlets appeared to be severe, but did not materially reduce the crop. The damaged fruitlets dropped off, and no definite frost blemishes were observed on mature fruits. Frogmore and Turkish Black suffered less damage to their fruitlets than other varieties. They are also said to be less susceptible in the blossom stage.

Plums.

The variety Avon Cross suffered most damage to fruitlets, while Victoria, Severn Cross, Utility and Bountiful were also affected.

Many of the fruitlets of Avon Cross also showed blistering of the skin after the frost, followed by russet spots on the surface of the mature fruits.

In Marjorie's Seedling some of the fruitlets showed well-marked russet frost rings accompanied by slight constriction (Fig. 3, A). These fruitlets matured to form normal shaped fruits, with no constriction, but with a more or less complete russet ring (Fig. 3, B).

Walnuts.

The pistillate flowers, or, if these were not yet formed, the buds where they were developing, were severely damaged. There was little varietal difference in the amount of injury, nor did it seem to depend on the stage of development of the flowers. Many trees failed to carry any crop, as a direct result of this damage.

Soft Fruits.—Raspberries.

Damage was very slight, and confined to a few of the oldest flowers. Malling G suffered more damage than other varieties, but not enough to affect the crop.

Strawberries.

Some of the first flowers were injured. The late variety Tardive de Léopold had relatively few open flowers, but a high proportion of these were damaged. All varieties suffered some damage, the early Madame Lefebvre rather more than others, and Huxley less.

Black Currants.

Much running-off occurred in the spring, but it was probably mainly due to cold, dry winds, and not so much to damage by frost.

Summary.

Frost damage symptoms observed on fruits during 1949 are described and illustrated.

Fig. 1.

Frost damage to leaves and fruitlets of James Grieve.

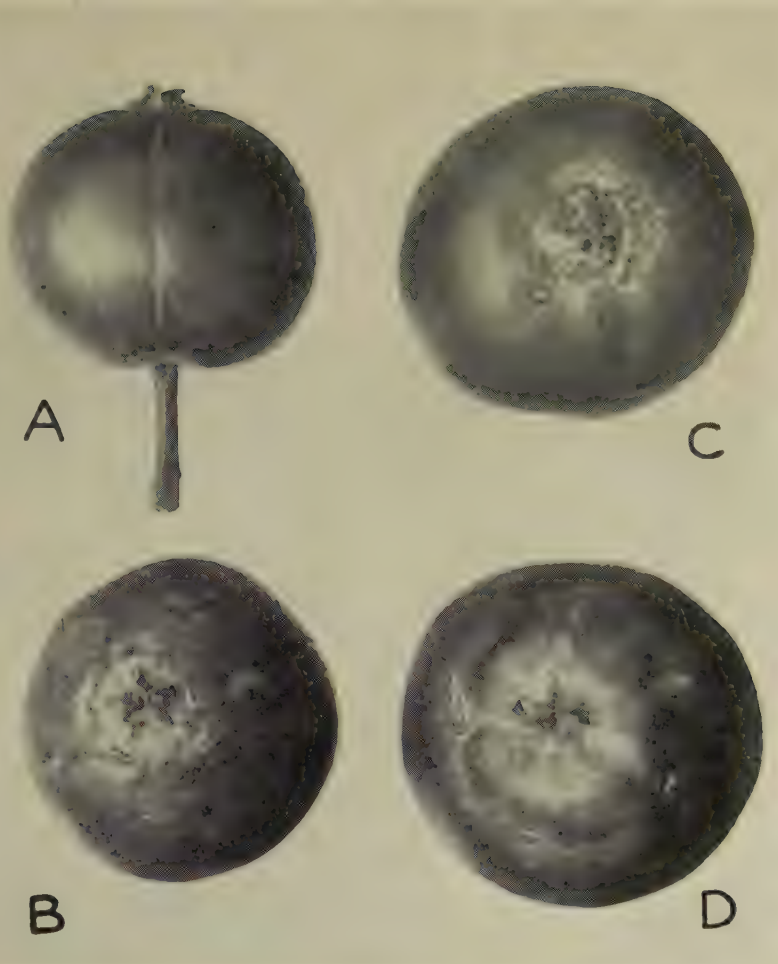

Fig. 2.

A. Frost line on Edward VII.
B. Russet patches on Edward VII.
C. Frost eye developed from green blotch. Orleans Reinette.
D. Early signs of frost ring, developing from green blotch, Ellison's Orange.

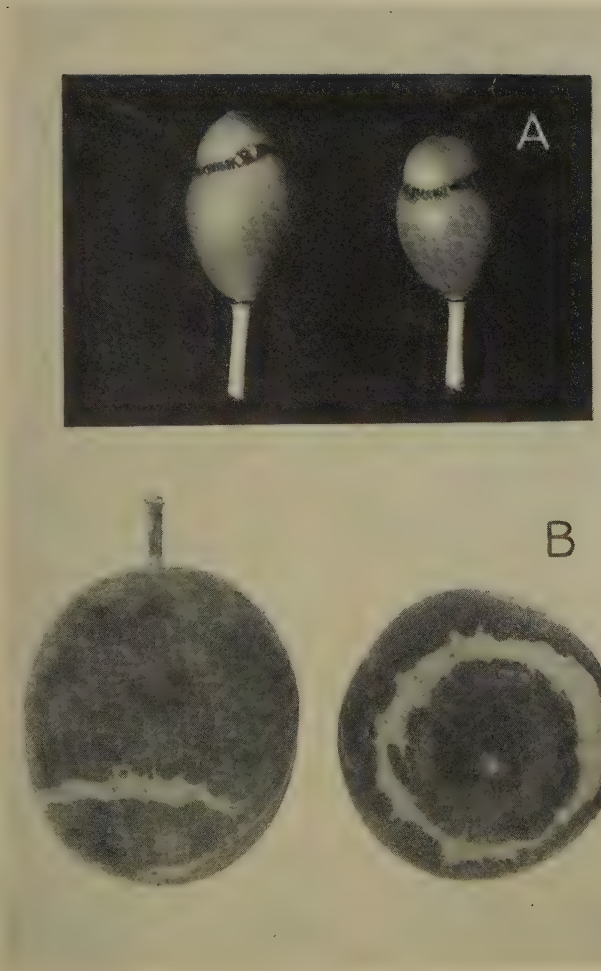

FIG. 3.

Frost rings on plum Marjorie's Seedling.

A. At end of May.

B. At time of picking.

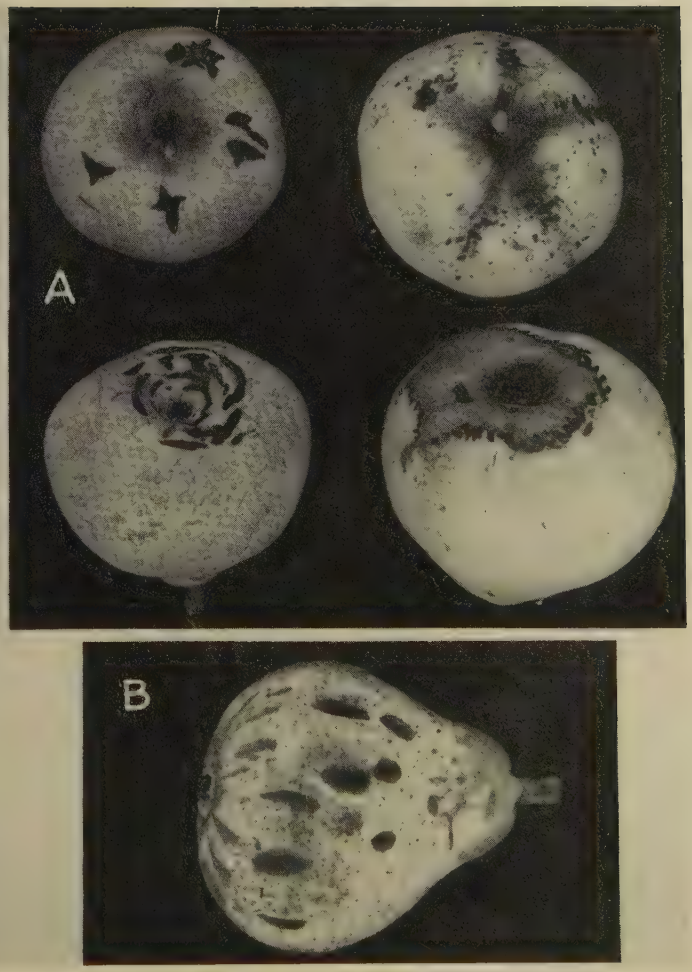

FIG. 4.

A. Frost blemishes on quince. ($\times\frac{3}{4}$).

B. Frost cracks on pear Williams' Bon Chrétien. ($\times\frac{1}{2}$).

STUDIES IN FRAMEWORK GRAFTING OF MATURE FRUIT TREES

V. FIFTEEN YEARS COMPARATIVE PERFORMANCE OF FRAMEWORKED AND TOPWORKED APPLE TREES

By R. J. GARNER

In 1942 the writer reported upon an experiment begun in 1935 (Garner, 1942) in which frameworking was compared with three methods of topworking. The stock trees were Newton Wonder and the scion was Laxton's Superb. The frameworking was all done by stub grafting and the topworking by three methods, rind grafting, rind grafting with retention of two branches for one year after grafting, and oblique-cleft grafting. It was shown that the frameworked trees suffered less from disease than any of the topworked, cropped heavily in their third season and continued to bear more fruit in subsequent years than trees worked by any of the other methods. Crop and trunk size records have been maintained throughout the fifteen years since re-working and the height and spread of the trees has been measured at intervals. This direct comparison between frameworking and topworking methods has revealed differences which are considered of sufficient importance to warrant a further report.

Material and methods.

A full description of the trees, which were thirteen years old when re-worked in 1935, was made in 1942. At that time sixteen of the topworked trees had died from " Silver Leaf " disease (*Stereum purpureum*) whilst three of the frameworked trees had also succumbed. Since then no further losses have occurred. The cultural treatment has been uniform in regard to manuring, spraying and pruning. For the first few years after grafting the trees were only lightly pruned to encourage early fruiting ; once this was established, the pruning was rather more severe. In recent years the trees have been allowed to fruit on extended laterals, two and three years old, cutting back a proportion each year.

Growth.

Area of cross-section of stem.

Within given stock-scion combinations the size of the trunk may be taken as an indication of the growth of the tree as a whole. Annual measurement of the increase in trunk size in this experiment revealed that the topworking methods, without branch retention, checked trunk thickening, whereas frameworking only did so in small degree. The trees in which branches were retained for one season behaved similarly to the frameworked trees during the first year after grafting, but a severe check followed upon the removal of the branches in the second year. The effect of grafting method upon the course of trunk thickening is shown in Fig. 1, where it will be seen that this has persisted and, 15 years after the operation, has been somewhat accentuated.

Height and spread.

The height and spread of the trees at the 7th, 11th and 15th year from grafting are shown in Table I. By 1941, the 7th year, the topworked trees had achieved a considerable spread, there was little difference in height but such difference as there was coincided with cropping, as shown in Table II ; the heavier the early crops the greater the spread. The frameworked trees, though not quite so tall as the topworked trees, have a greater spread and have maintained their lead during the past four years. There is a distinct difference in shape of tree-head between topworked and frameworked trees as can be seen in Fig. 2.

Cropping.

The early and heavy cropping of frameworked trees is one of their outstanding features (Garner and Walker, 1938) and it has already been shown (Garner, 1942) that topworked trees are much slower to crop and that the first few crops on topworked trees are of inferior quality. The greater cropping power of frameworked trees is well shown in Table II. During the fifteen years since grafting the mean crop from the frameworked trees has amounted to 50 bushels, whilst the heaviest cropping topworked trees, those done by the oblique-cleft method, have yielded only 30 bushels. Topworking by rind grafting with branch retention has yielded 28 bushels and rind grafting without branch retention 24, rather less than half the yield of the frameworked trees.

It was thought possible that the early and heavy cropping of the frameworked trees might be accompanied by a falling off in fruit size. The records taken in the last three years of heavy cropping, namely 1945, 1947, and 1949, showed that though the fruit was very small in the last year, probably due to drought, this reduction in size was general throughout the experiment. An examination of the

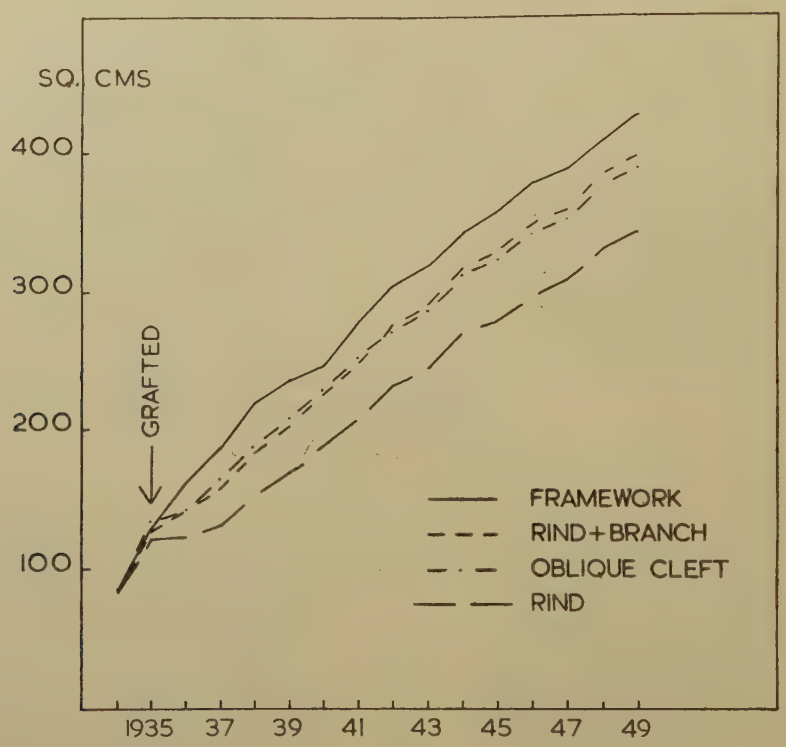

Fig. 1.

Area of cross section of Newton Wonder trunks after re-working with Laxton's Superb in 1935. Average for trees on five rootstocks. Note persistent effect of mode of grafting upon trunk thickness.

data presented in Table III reveals that fruit size was not correlated with the method of re-working. The slightly smaller fruit from the frameworked trees in 1947 is probably related to the exceptionally heavy cropping.

Discussion.

One of the most striking early results of frameworking is the rapid return of the trees to full cropping whereas the cropping of topworked trees is considerably delayed, though the vigorous shoots from the new scions on topworked trees leads the observer to forecast that such trees will eventually settle down and attain the cropping capacity of the frameworked. This has certainly not happened in this trial. The topworked trees, fifteen years after grafting, have still not reached the size of those frameworked and year to year records reveal that neither in size of head nor in thickness of trunk have the topworked gained upon the frameworked. For example, using trunk size as a general growth

indicator it is clear that the best topworked methods, the rind with branches and the oblique-cleft methods, were about a year behind in 1937 and nearly two years behind by 1947.

The topworked trees are slightly taller than the frameworked but are distinctly less spreading. The reduction of the heads of topworked trees at grafting time may have given the interplanted trees, not in the trial, time to occupy the available space and this may have, in part, discouraged increase in spread.

The comparatively heavy cropping of the frameworked trees has been maintained, the accumulated crops being almost twice those of the average for the topworked, namely, 50 and 28 bushels respectively. The difference between the performance of the topworked trees is also noteworthy, the oblique-cleft grafted trees have given 25 per cent. more crop than the rind grafted. The benefits following the retention of two branches for one season have persisted and demonstrate the value of this procedure. The heavier cropping of the frameworked trees has not resulted in a reduction in fruit size, compared with the fruits from topworked trees. In 1949, when a severe drought occurred, all the fruit was extremely small yet the heavier cropping frameworked trees bore fruits equal to the average size of those from the topworked trees.

The early advantages which come from frameworking, reported in 1942, have thus persisted throughout the fifteen years since the experiment began.

TABLE I.

HEIGHT AND SPREAD OF TREES AT FOUR YEAR INTERVALS IN METRES.
MEANS PER TREE.

Method of grafting.	No. of trees.	1941.		1945.		1949.	
		Height.	Spread.	Height.	Spread.	Height.	Spread.
Rind	7	3·0	3·8	4·6	4·5	5·0	4·7
Rind with branches ..	10	3·3	4·1	4·8	4·7	5·1	5·0
Oblique-cleft ..	7	3·2	4·2	4·8	4·6	5·1	4·8
Framework	8	3·2	5·7	4·4	5·8	4·7	6·0

TABLE II.

ACCUMULATED CROPS AT INTERVALS.
MEANS PER TREE.

Method of grafting.	No. of trees.	1935-37 lb.	1938-42 lb.	1943-45 lb.	1946-49 lb.	Total crop, bushels.*
Rind	7	0·4	161	393	414	24
Rind with branches	10	0·8	212	438	486	28
Oblique-cleft ..	7	9·3	278	478	455	30
Framework ..	8	165	565	653	624	50

* Taking one bushel as equal to 40 lb.

TABLE III.

FRUIT SIZE AT 11, 13 and 15 YEARS AFTER GRAFTING.
WEIGHT OF 100 FRUITS IN LB.

Method of grafting.	No. of trees.	1945.	1947.	1949.
Rind	7	14·7	14·6	9·1
Rind with branches	10	14·8	15·1	9·0
Oblique-cleft	7	14·0	14·7	7·5
Framework	8	14·2	13·5	8·7

Summary.

A description is given of fifteen years' performance of the apple variety Laxton's Superb grafted by one frameworking and three topworking methods upon thirteen-year-old trees of Newton Wonder.

The retention of sap-drawer branches for one season after topworking resulted in somewhat heavier cropping than plain rind grafting ; the oblique-cleft grafted trees cropped more heavily than either of the other topworking methods. Frameworked trees had thicker trunks, more spreading branches and bore much heavier crops than those topworked. The individual fruits from the heavy cropping frameworked trees were as large as those from topworked trees.

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Fig. 2.
Laxton's Superb apple trees, fifteen years after grafting on thirteen-year-old Newton Wonder. Topworked tree on the left, frameworked on the right. Note effect of method of grafting upon shape of head.

TWO NEW RASPBERRY VARIETIES

By N. H. GRUBB

Some 25 raspberry seedlings have been sent out from East Malling for preliminary trial, and four have already been named, i.e., Malling Promise, Malling Enterprise, Malling Landmark and Malling Notable. The time has now come to add two more to this list.

Malling Jewel (previously Seedling J), raised at the same time and from the same parents (Preussen × Seedling 23/50) as Malling Enterprise, has done well in many districts, and in some is preferred to Malling Enterprise. One report, from Devonshire, indicated a crop equivalent to ten tons per acre, approximately double the heaviest yield of any variety ever recorded at East Malling.

Malling Exploit (previously Seedling X), raised at the same time and from the same parents (Newburgh × Seedling 30/8) as Malling Promise, has in more than one trial appeared preferable to the latter, having surpassed it in crop, fruit size, colour and dessert quality. Whilst this variety has not yet been as widely tested as Malling Jewel, it seems likely to be adaptable to a fairly wide range of environments, having done well at East Malling, in the National Fruit Trials at Wisley, in Angus, and in a garden in Cumberland.

Malling Jewel (formerly Malling J, 33/54).

Growth vigorous ; canes stout, 6 to 7 ft. or more, always fairly numerous ; glabrous or nearly so. Habit stiffly erect, seldom much branched. Colour somewhat variable, but always more or less red or purple ; little glaucous.

Spines tinged, moderately numerous, but small and inconspicuous except on young plants and the lower parts of canes of old plants.

Leaves considerably convex and rugose, in dry seasons approaching the appearance of those of Pyne's Royal and Superlative A.

Cropping usually good, sometimes exceptionally heavy.

Fruit ripens second early, after Lloyd George and Malling Promise, but before mid-season varieties such as Newburgh. Large, sometimes very large, much like that of Malling Enterprise, but more conical. Colour fairly bright red, becoming somewhat dark at full ripeness. Always " plugs " easily, i.e. does not adhere to the receptacle. Firm enough for all purposes. Drupelets medium size or less. Dessert quality fair, about equal to that of Malling Enterprise.

Malling Exploit (formerly Malling X, 51/84).

Growth vigorous ; canes fairly stout, tall, often over 7 ft. ; numerous, sometimes very numerous ; glabrous or nearly so. Habit somewhat spreading, though less so than that of Norfolk Giant ; often considerably branched in the first year after planting, subsequently much less. Colour much like that of Malling Promise, greenish in summer, becoming light brown below, darker above, in autumn and winter ; little glaucous.

Spines mainly tinged, but usually some dark coloured also ; fairly numerous, not very troublesome.

Leaves flat or flattish, similar to those of Malling Promise, but leaflets somewhat narrower.

Cropping usually heavy, sometimes outstanding.

Fruit ripens early, with or just after Lloyd George and Malling Promise. Very large, usually larger than that of any other Malling variety yet sent out for trial ; shape fairly regular, oval-conical ; usually without the green tip sometimes occurring in Malling Promise ; good bright red, brighter than Malling Promise, not becoming very dark when fully ripe. Usually " plugs " easily, i.e. does not adhere to the receptacle. Firm enough for all purposes. Drupelets rather large. Dessert quality nearly first class, better than that of Malling Promise ; with Malling G about the best of the Malling series so far produced.

OBSERVATIONS ON THE DEVELOPMENT AND ANATOMY OF HOP LAYERS

By DOROTHY J. WILSON

Hop plants are propagated in Great Britain from cuttings. These are obtained by covering a portion of the stem with soil, causing it to thicken during the summer. When the aerial part of the stem dies at the end of the season, the part beneath the soil remains alive and can be divided into cuttings, each of which must have at least one node furnished with buds.

Commonly only the bases of the stems are covered, to a depth of about 6 in., giving one "strap cut" per stem. Recently, however, methods have been studied whereby the stems are buried for several feet of their length to produce "layers" which can be divided into many cuttings (Keyworth and Wilson, 1948; Keyworth *et al.*, 1948). Advantage was taken of these investigations to observe the development of the layered stem and to study its anatomy.

Plants of the Wye seedling OM26 were used for these studies. On 4th June, 1947, stems already 9 or 10 ft. long were buried in the soil for some 7 ft. of their length and their exposed tips trained up strings. These stems subsequently grew a further 12 or 14 ft. and produced abundant foliage and hops. At the end of the season they died back to soil level.

At fortnightly intervals throughout the summer, one or more of the layered stems were removed from the soil and sample pieces fixed and preserved for sectioning. On some occasions pieces of unlayered stem were also preserved. The fixative, form-acetic-alcohol*, was taken out into the field and pieces of stem 1 or 2 in. long were immersed in it as soon as they were cut. Sectioning was carried out during the following winter, using a sledge microtome.

The development of the layer.

At the beginning of June the hop stems were green, hexagonal with a hollow centre, and carried numbers of small, sharp, hooked hairs along their ridges. The nodes with their pairs of opposite leaves and small axillary buds were several inches apart, except at the tip, and extension growth was proceeding rapidly. The extension growth of the internodes ceased when they were buried.

Stems lifted after a fortnight in the soil (19th June) had lost their leaves, were less green than when put down, and roots were beginning to appear towards the crown of the plant. Those lifted on 3rd July were beginning to thicken and to lose their hexagonal shape.

The next specimens, collected on 16th July, had abundant fibrous roots along the whole of the layered length. The stem surface was no longer green and was becoming corky. Later samples were progressively thicker and more corky, and showed gradual swelling of their buds. By the end of the season the mature layer was a stiff rope-like organ with a rough brown surface and with large resting buds enclosed in scales. Prominent white lenticels had also developed, a characteristic of this and some other varieties.

A series of transverse sections from the preserved stems was stained in safranin and light green. Fig. 1 illustrates that of a stem cut from the plant before layering (4th June). There is a wide pith and the groups of primary xylem with their small vessels can be readily seen. Secondary xylem containing very large vessels, and a very narrow band of secondary phloem are already present. The cortex contains resin ducts, and the bands of strongly thickened fibres just below the epidermis are particularly well-developed at the corners.

The stem which had been in the soil for two weeks (Fig. 2) has a greater width of secondary vascular tissue (chiefly xylem), but otherwise differs little from that in Fig. 1. The stem lifted after four weeks showed a pronounced increase in secondary phloem, and that lifted after six weeks had more phloem than xylem. The expansion of the phloem throughout the season is the most noticeable feature of secondary thickening in the layer.

The anatomy of the mature stem and layer.

As well as layered and unlayered stems of OM26, layers and strap cuts of the Wye seedling AEE55, and strap cuts of the variety Fuggle were also examined both in transverse and longitudinal sections. Except that in the strap cuts the cells were smaller and the tissues denser, there was no

* 90 c.c. 70 per cent. ethyl alcohol; 5 c.c. glacial acetic acid; 5 c.c. formalin.

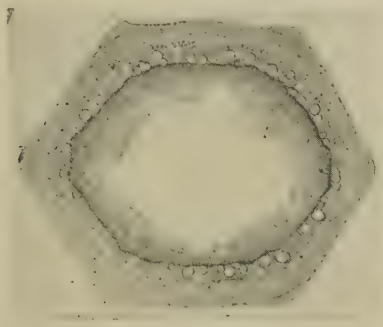

Fig. 1.
June 4th. Transverse section of green stem.

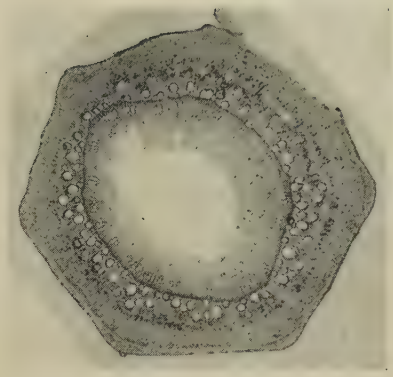

Fig. 2.
June 19th. Stem layered 2 weeks.

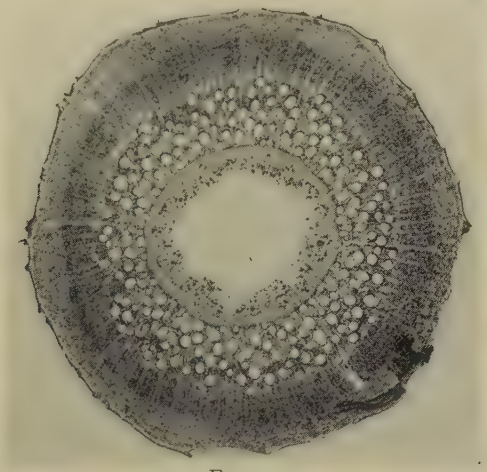

Fig. 3.
July 16th. Stem layered 6 weeks.

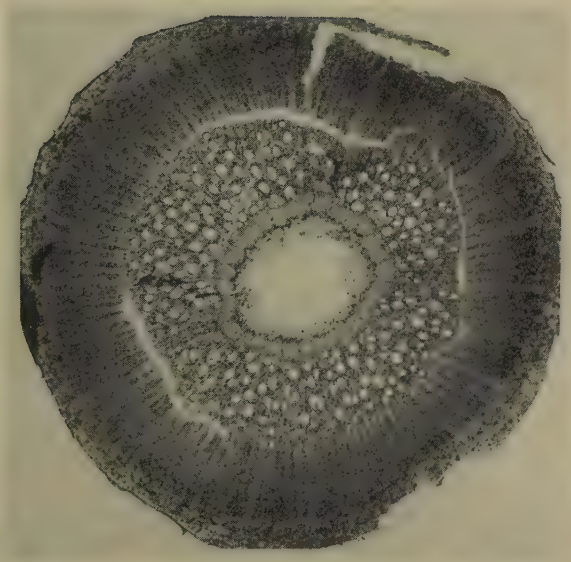

Fig. 4.
September 12th. Mature layer.

Fig. 5.
September 29th. Unlayered stem.

[face p. 76

apparent difference in internal stem structure between strap cuts and layers, or between layers of the two varieties.

The vascular system is of the vine type, the bundles remaining separated by rays of parenchyma even after secondary thickening has taken place. These medullary rays are increased by cambial activity like the bundles. In the phloem zone of the mature stem or layer they can be easily distinguished but in the xylem zone they are often crushed between the developing vessels. They can, however, be traced right through to the pith. The bundles themselves appear to contain smaller vascular rays, so that both secondary phloem and xylem occur as narrow radial strips of tissue. The vessels are very large and can easily be distinguished by the naked eye. In the layer many of the phloem cells appear to be of the parenchymatous type. Sieve tubes and groups of fibres are also present.

At the end of the season both layered and unlayered stems have extensive secondary xylem, but in the layered stem there is very much more phloem. In the sections of OM26 illustrated (Figs. 4 and 5) the proportions of phloem to xylem are 4 : 3 in the layered stem and $<3 : 4$ in the unlayered stem.

Storage of starch.

Another series of transverse sections from the stems of OM26 was stained with iodine. No starch was found in the stem taken two weeks after layering, but the next specimen (3rd July) contained starch in the oldest regions of the secondary phloem and xylem. The starch occurred in the ray cells and parenchyma cells and was present as one composite grain or aggregate of small grains in each cell. In the layer cut on 16th July starch was present in parenchymatous cells throughout the phloem and xylem zones and also in the cortex. In the next specimen it was also found in the rays between the primary xylem bundles and in the outer cells of the pith. Later layers showed no further change in starch distribution. Diagrams 1-4 (Fig. 6), which are based on the radial measurements of the

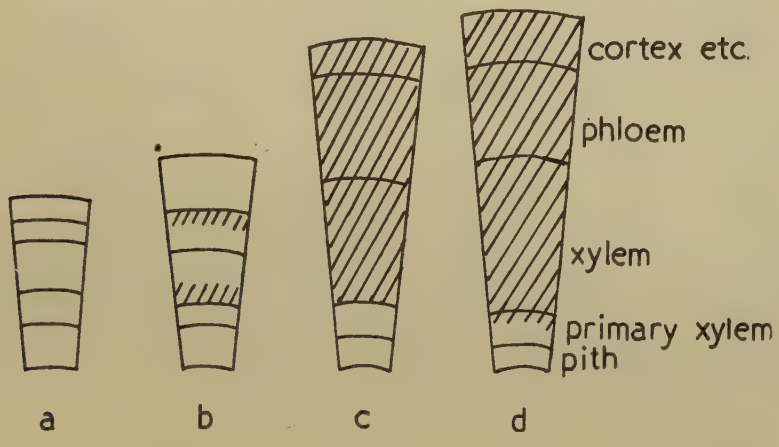

Fig. 6.

Distribution of starch as the layer develops (a) Layered 2 weeks; (b) Layered 4 weeks; (c) Layered 6 weeks; (d) Layered 8 weeks. Starch is present in the shaded tissues.

individual sections examined for each date, represent the distribution of starch in the tissues at 2, 4, 6 and 8 weeks after layering. The first and third correspond to the stems illustrated in Figs. 2 and 3.

At no time was starch found in unlayered stems.

Presence of tannin.

A third series of sections from the same specimens was treated with ferric chloride as a test for the presence of "tannin". It was almost completely absent in the green stem at the time of layering, but appeared in considerable quantity as the layer developed, being eventually present in many cortical cells, ray cells and some phloem and pith cells; whole cells appeared to be full of tannin (tannin sacs) and a granular structure was apparent in some of them.

Tannin was also found in the outer tissues of unlayered stems at the end of the season.

The effects of layering.

The layering process evidently causes definite modifications in the physiology of the hop stem. Although the production of secondary xylem appears to continue at about the same rate as in the unlayered stem, the rate of production of secondary phloem and of ray tissue to the outside of the cambium is increased. This extra tissue acts as a storage organ for the deposition of starch. The rapid radial growth of the inner tissues causes the rupture of the epidermis and a layer of cork develops in its place. At the same time root formation is stimulated throughout the buried length of stem, and the axillary buds at the nodes, which would develop into laterals on an unlayered stem, become swollen and fleshy " winter " buds, and remain dormant until the spring. The change of environment thus converts the normal aerial stem into what is in effect a rhizome.

The conditions necessary for layer-formation.

It was known that hop stems left lying on the surface of the ground often rooted at the nodes but did not form typical layers unless covered with soil. Plants of OM26 were therefore used in seeking indications of how the four factors, darkness, moisture, soil and position, were concerned in the formation of layers. The following treatments were applied in June :

Plant 1. Stems were enclosed in a vertical waterproof jacket about 5 ft. high in order to keep them in the dark and dry.

Plant 2. A similar jacket was placed round stems laid flat on the ground for 5 ft. This jacket rotted on the under side where it was in contact with the moist soil, so that although light was excluded, the atmosphere became moist.

Plant 3. The stems were suspended horizontally in a tent of thick sacking which excluded light. To begin with this was kept moist by watering, but it dried out so quickly during the hot weather that it was not possible to maintain moist conditions and watering was abandoned. At the time of lifting it was evident that the atmosphere inside had been drier than in 2.

Plant 4. Stems were enclosed in a drum full of soil so that they were growing vertically through 2 ft. of soil above ground level.

Stems layered in soil in the normal way and stems trained vertically in full light and air were also observed and have already been described.

The stems from the above treatments were uncovered in October. Those of plant 1 were brown and corky and slightly thickened near the base. There were no roots, and the buds were well-developed within 9 in. of the soil, but few and very small higher up. Plant 2 had well-thickened stems with brown corky surfaces and prominent lenticels. Roots were present and the buds were well-developed (some of them expanding) along the whole of the covered portion. Three of the six stems covered on plant 3 were thickened, brown and corky, but the others were still more or less green. Roots were present along the whole length, particularly on the thicker stems and towards the crown, but they had all dried up at the time of lifting. Well-developed buds were present within 2 ft. of the crown and fewer and smaller ones on the rest of the stem. Treatment 4 gave well-thickened stems with good strong buds and abundant roots.

Discussion.

The results of these treatments indicate that although a moist medium is essential for roots to arise on the stem, it will begin to thicken and develop its buds if light is excluded ; this will take place whether the stem is supported vertically or put down in a horizontal position. Layering in soil increases the thickening and bud development, presumably because it encourages root production, thus making extra food supplies available to the stem. Such ready root production along the layered part of the stem must account for the improved vigour of the exposed part, which, as noted elsewhere (Keyworth *et al.*, 1948) often grows more strongly and to greater length than unlayered stems on the same plant.

From a practical point of view, when layers are to be used for propagation it is desirable for them to be well-thickened so that the cuttings have a sufficient store of food to give their buds a good start in spring. Conditions which encourage quick rooting when the stem is layered and so stimulate strong growth and abundant healthy foliage on the exposed part also encourage starch production and thickening. Hence the stem should preferably be laid in moist, friable soil, a point which has been found important in practice. Stems put down into very dry soil or caked soil, unfavourable to quick rooting, have been observed to make very poor layers. Once the stems are ridged over with dry soil, later rains are very largely shed and do not penetrate to where the stem lies.

Acknowledgements.

The author wishes to thank Dr. W. G. Keyworth, who instigated this work, for his help and suggestions throughout.

Summary.

The development of layered hop stems throughout a growing season was studied and their internal structure examined. The layer was found to develop a large amount of phloem and ray tissue and a store of starch.

A preliminary study of stem behaviour under the influences of darkness, moisture, position and soil is also described.

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——— and Wilson, D. J. (1948). Experiments on the layering of hops. II. Layering young plants. *J. hort. Sci.*, **24**, 206-13.

WEATHER CONDITIONS DURING 1949

By A. P. PRESTON

The year has been exceptionally dry and sunny.

Rainfall amounted to 20·94 in., 5·30 in. below the thirty years' average, and 5·03 in. less than in 1948. This is the lowest annual rainfall at East Malling since 1921 when only 12·98 in. were recorded. The months of May and October alone had rainfall above the average, and at the end of September, when the apple harvest was nearly finished, the total rainfall was 9·66 in., 7·96 in. below the average for the first nine months of the year. The serious water shortage adversely affected the top fruit crops (see Farm Report). Indeed, the position was far more serious than the rainfall figures for 1949 show

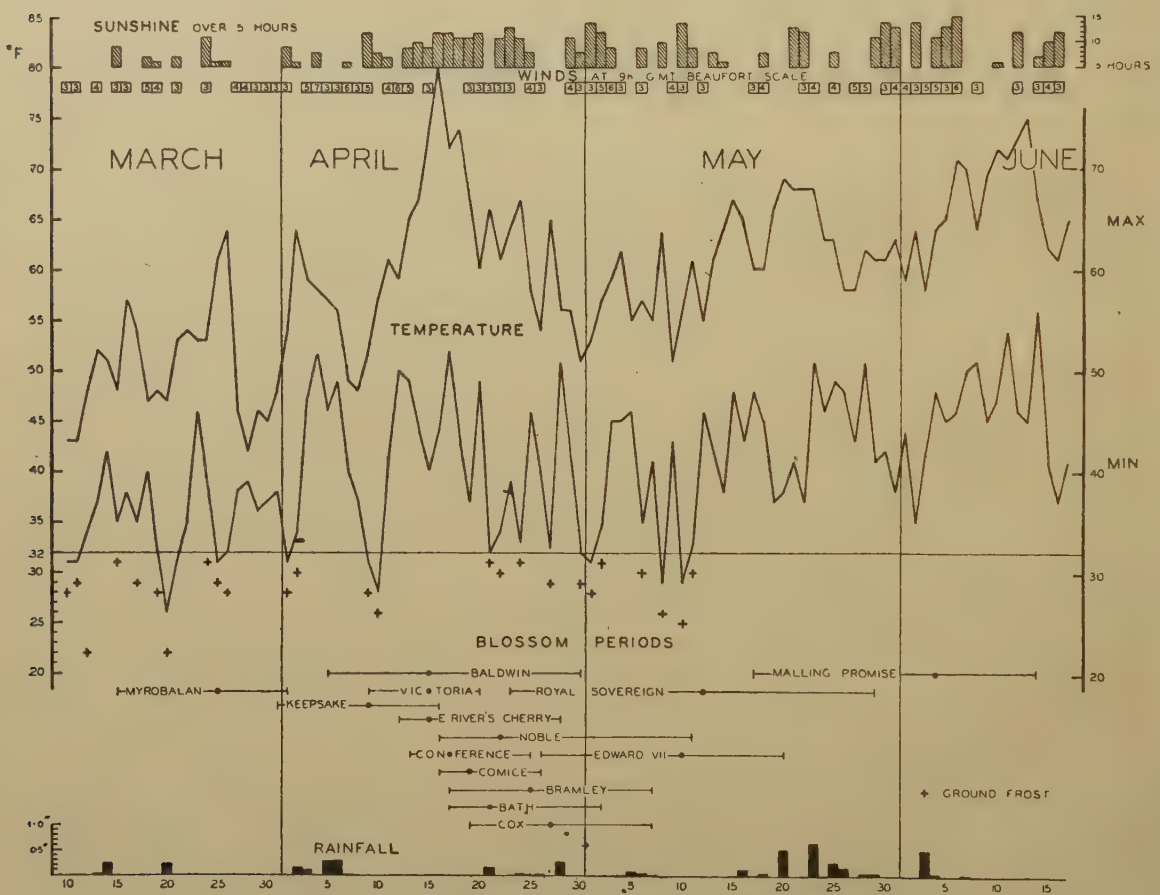


Diagram showing weather recorded during the blossoming season, 1949.

for in addition to the dry winter, spring and summer, it should be remembered that with the exception of December, 1948, average monthly rainfall had not been recorded from September, 1948 to April 1949, inclusive. The heaviest rainfall during 1949 occurred on 20th October, when 1·50 in. fell during two thunderstorms. This month, the wettest of the year, with 7·50 in. rainfall, was not a record, for in October, 1939, 8·31 in. were recorded.

Snowfalls were recorded on 1st, 2nd and 6th March, but the snow only settled on the 6th.

Summer temperatures were much higher than last year, while September and October were unusually warm and mild. Serious late spring frosts were again absent ; the lowest screen temperature during May was 29° F. recorded on the 8th and 10th, but ground frosts during this month damaged

some of the early strawberry blossoms. Pollination conditions for plums and cherries during April were generally very good, but north-easterly winds with low maximum screen temperatures were recorded during the first few days of May when the apples had just begun to flower. Nevertheless a good crop was set, helped no doubt by rain during the last two weeks of May. The first ground frost of the autumn was 29° F., recorded on the 27th October.

Sunshine during the year amounted to 1,935·5 hours, 542·4 hours above the thirty years' average and 190·5 hours more than last year. This is the sunniest year we have recorded at East Malling since our observations began in August, 1914; the previous sunniest year was 1929 with 1,800 hours sunshine. March was the only month in which sunshine was below the average, while February, with 121·1 hours, created a record for that month at this Station.

Crop weather station at Throwley, Kent.

During December a crop weather station was established at Newlands Farm, Throwley, under the Agricultural Meteorological Scheme, as a sub-station of East Malling, by courtesy of T. Neame, Esq., and regular readings began on 1st January, 1950. This station is on a young top fruit plantation 500 ft. above sea level, and approximately 1½ miles north-west of Charing Hill. The new station should give interesting and valuable climatological data, besides providing material for comparative weather study with the East Malling station, which is 132 ft. above sea level.

Acknowledgement.

The writer wishes to thank Mr. G. F. Trowell for assistance during the year and Miss J. M. S. Thom for computing the data and preparing the diagram.

SUMMARY OF METEOROLOGICAL OBSERVATIONS DURING 1949.

Month.	Temperature in Screen.					No. of Ground Frosts.	Rainfall.			Sunshine.			Soil Temperatures.		
	Mean maximum.	Mean minimum.	Highest.	Lowest.	Mean.		Total in inches.	Heaviest fall in a day.	30 years' average.	Total hours.	Average per day.	30 years' Average.	4 inches.	8 inches.	2 feet.
January	47	35	53	26	41	13	0·90	0·30	2·53	60·7	2·0	45·8	37·9	38·9	41·0
February	50	33	57	18	41	14	0·95	0·37	1·82	121·1	4·3	67·3	37·2	37·9	40·0
March ..	47	34	64	25	40	16	0·88	0·31	1·52	105·5	3·4	118·7	38·7	39·3	41·3
April ..	61	41	80	28	51	7	1·35	0·29	1·99	225·5	7·5	131·7	51·7	49·7	49·7
May ..	61	41	69	29	51	5	2·14	0·66	1·77	228·7	7·4	198·3	54·8	54·2	54·5
June ..	70	46	88	35	58	0	0·58	0·51	1·44	254·8	8·5	204·0	63·2	62·0	60·8
July ..	76	51	87	40	63	0	0·54	0·27	2·20	265·8	8·6	190·7	69·5	68·8	67·9
August ..	74	51	86	42	62	0	1·36	0·55	2·27	236·4	7·6	181·9	66·3	66·1	67·0
September	72	54	86	44	63	0	0·96	0·26	2·08	177·1	5·9	145·8	63·6	64·0	65·4
October	62	44	72	25	53	5	7·50	1·50	2·82	127·7	4·1	100·9	52·9	54·3	57·9
November	49	36	56	23	42	15	2·59	0·45	3·15	73·0	2·4	53·7	40·9	42·2	45·9
December	48	36	56	26	42	15	1·19	0·26	2·65	59·2	1·9	39·1	40·2	41·0	43·6
Totals ..						90	20·94		26·24	1935·5		1477·9			

STATISTICS

THE PURPOSE AND DESIGN OF CALIBRATION TRIALS

By S. C. PEARCE and J. TAYLOR

I. The Purpose and Value of Calibration Trials

Introduction.

When designing an experiment every effort should be made to use trees as uniform as possible, but there are limits beyond which standardization cannot go. Thus, a recent investigation into crop variability in apples (Pearce, 1949) showed that coefficients of variability as high as 30 per cent. were by no means unusual even with clonal material that had been well looked after. Since trees vary so much, it seems worth while to estimate the potentialities of each tree before the experiment begins and to judge its actual performance by reference to this estimate, but can this effectively be done ? No effective method is known, at least for apples, if the treatments take effect from the time of planting ; as, for example, in trials of different methods of tree-building or of planting and in those experiments in which soil treatments start before or at the time of planting. This is because the size of an apple tree at time of planting has little effect on its ultimate growth (Brase and Tukey, 1936 ; Shaw, 1942 ; Dorsey and Hough, 1943 ; Pearce, 1949). This should certainly be so if very large, very small, diseased or malformed trees are avoided, as they should be when planting out trials. On the other hand, Lutz (1938) did find a continuing effect of size of planting in pecan trees. If, however, treatments are deferred for some time, it has been found for many species that valuable reductions in error during the experimental period can be effected by making use of earlier measurements. This is done by the well-known method of the analysis of covariance (Fisher, 1938), which is useful whenever part of the experimental error can be explained by variation in the preliminary measurements.

It is the purpose of this paper to discuss actual examples where the method has been used and the layout of orchards specially designed for its use. The extension of the method to commercial orchards will also be referred to.

It might be thought that the method of calibration would add to the time needed to secure results. On the contrary, it facilitates experiment. As will be explained in Part II, orchards for future experiments can be designed with such flexibility that they can be planted before the treatments are chosen. Consequently, if a research station makes a practice of planting such orchards, experiments can be started as soon as treatments have been selected without waiting for special material to be raised.

It should be emphasized that this method is not new, an example having been given by Parker and Batchelor (1932) nearly twenty years ago. Since then there has been some inconsistency of nomenclature. Some (e.g. Murray, 1934) have described the trees before the application of treatments as forming a " uniformity trial ", but this is hardly suitable when the purpose is not the study of uniformity. Others (e.g. Pearce and Hoblyn, 1948) have preferred the term " blank trial ", but it has been found that this emphasis on a merely negative aspect leads to confusion. The name to be used here is " calibration trial " from analogy with the calibration of guns, a process in which the individual performance of each is tested in order to reduce error in the future.

Review of previous work.

The first advocate of calibration trials with perennial plants appears to have been Eden (1931). He commented that with annuals the method is not always very valuable. He cited a trial that was conducted " blank " for three years with treatments added in a fourth, and points out that greater precision would have been attained if four times as many plots had been used in one year. For perennials, on the other hand, he thought that the reverse might be true and that advantage might well result from a three-years " blank " trial followed by one year of treatments. He cited data with tea in support of this contention. Subsequent investigation (Eden, 1935) showed there to be a high correlation between the crops of two years in the same pruning cycle, though the correlation was unimportant if pruning intervened.

Cheesman and Pound (1932) considered this approach in connection with cacao, a crop the plants of which are sometimes uniform for age and sometimes heterogeneous, newly planted

bushes occurring between others decades old. For trees heterogeneous for age they recommended that no trial should be attempted unless past yield records are available to allow of the use of covariance. For trees uniform for age the advantage of past records was less, but still considerable. They found also that years of very heavy crop were not typical and gave low correlations with crops in most years. They further remarked that cacao is commonly biennial in habit, which made them question if the need for covariance could not be largely avoided by using crop in two-year periods.

Murray (1934) investigated the value of the method of covariance with rubber yields and concluded that considerable reductions in error could be effected by the use of previous crop records. The reduction was greatest when the interval between the correcting and corrected crops was least.

Webster (1939) correlated yield of oil palms in one- and two-year periods with previous yields and found useful correlations. It appears from his table that the larger the plot the better the correlation. He also commented that biennial bearing could vitiate the accuracy of results based on a single year's crop. This paper showed that useful experiments could be designed upon established oil palms, if a correction by covariance was made on the basis of past performance.

Parker (1942) made a comprehensive study of the best variate for reducing the error of an orange fertilizer trial. He had crop records for six years before the start of the experiment as well as top volume, area of cross-section of trunk when the treatments were applied, and other records. Further, a number of " check plots " was left from which estimates could be made of the expected yield of the experimental plots. The best correcting variate was the previous crop, which was made even better by using the results from the check plots as well.

At East Malling (Pearce, 1949) an investigation was made to find the best way of reducing the variability of apple trees when the treatments had been applied to grown trees. The tables show that for a short-term experiment previous yield is best for the correction of crop records, but for a longer period trunk girth is to be preferred. These results are quite different from those of Parker (*supra*) with another crop.

From the references given it is plain that results obtained with one species do not necessarily apply to others ; but it is also plain that where a search has been made for past measurements to correct for future variability success has frequently resulted. The writers believe that a wider knowledge of the inter-relationships of measurements at different ages is badly needed. Given the cropping or growth of a set of trees, what measurements made in the past will most satisfactorily explain the variation encountered ? With the use of such measurements startling reductions in variability can be made in appropriate cases, thereby obviating the need to attempt the reduction of error by the use of additional replication.

Experience at East Malling with apple trees.

A cover crop trial upon commercially planted trees at East Malling will illustrate the usefulness of the approach. The crop for the years 1941-44 gave a standard error of 14·3 per cent. of the mean plot value, the yield of the clean cultivated control plots being larger than that of plots under some cover crop treatments and smaller than that resulting from other similar treatments. The differences, however, were not significant. A correction by the method of covariance upon crop in the years 1937-40 reduced the standard error to 6·1 per cent. and made it clear that the control had been significantly the least fruitful treatment.

The usual practice, however, is to correct crop by trunk girth. Thus in a cover crop trial (for design see Rogers and Raptopoulos, 1945 ; also " Cover Crop Trial, 1940 " in Pearce and Hoblyn, 1948) the standard error of crops of Cox's Orange Pippin apple in the years 1940-43 was reduced from 20·1 to 15·7 per cent. by means of covariance upon trunk girth in the autumn of 1939. In another trial upon commercially planted trees at East Malling (for design see Rogers, Raptopoulos and Greenham, 1948) the standard error of the crops of the three-tree plots during the period 1941-42 was reduced from 14·4 to 9·8 per cent. by correction upon trunk girth in autumn, 1940.

A warning must be given that a correction by covariance can be ineffective if there are too few error degrees of freedom, because the gain in precision does not balance the effect of the loss of a degree of freedom. Thus, in one trial at East Malling there were two pruning treatments in ten randomized pairs. Crop in 1945-48 gave a standard error of 27·4 per cent. : correction for trunk girth, measured in the autumn of 1944, reduced this to 24·5, and brought the difference of the pruning methods to the verge of significance. It would be fallacious to argue from this, however, that fewer replicates could have been used had the correction to the error been foreseen at the time of planning. The use of eight replicates together with covariance would have given only six degrees of freedom for error, whereas ten replicates without covariance give nine, an increase that more than balances the reduction of error. In this case nine replicates would have been needed to give the same accuracy with covariance as ten without, a negligible reduction in the size of the experiment.

These reductions in error obtained by the use of covariance corrections are quite usual, the examples given being typical and not specially selected to illustrate the point. Exceptions to the effectiveness of calibration, though occasionally met with, are rare. For example, the reduction in error in the last example was useful but less than might have been expected.

It should be remembered that a tree takes some time to establish itself and that useful relationships are not to be expected while it is still young. Experience at East Malling suggests that a calibration trial of apples should not be used experimentally until at least five years from planting if the full benefit of the correction upon trunk girth is to be obtained.

From the literature reviewed it will be realized that, although this has proved the best method for apples under East Malling conditions, some measure of vigour or prior cropping other than measurements of trunk girth may be preferable for some crops. The best character to use for any particular crop can only be determined by experiment. Moreover, even in the case of apple trials it may be useful to supplement trunk girth by another record. Thus if a set of trees is suspected to be deficient in potash, it may be valuable to take a leaf scorch record at the start, and analyse the results correcting for this as well as for trunk girtn.

It is not only in cropping trials that calibration has been found valuable. In spraying trials it may be useful to correct for the prior distribution of the pest or disease. Thus in a trial of winter and summer spraying against red spider the number of eggs on sample leaves was counted on the 4th June, 1947. An analysis of *log* $(n + 1)$, where n was the number of eggs in a sample, gave a standard error of 0·884. When a correction was made for a similar count taken shortly before the summer spray was applied, the standard error was reduced to 0·434. Marked reductions in standard error were also obtained for other counts of eggs and of mites, made in 1947, in this trial, on correction for the pre-treatment count. In the same trial in 1948, however, no significant correlations were found between pre- and post-treatment counts, and calibration was ineffective.

Short cuts in the analysis of covariance are better avoided. Thus, it is possible to substitute an analysis of variance on the *change* in tree performance when treatments are applied ; but such methods always involve an assumption of some sort, often not explicitly stated. If the assumption is justified, work will have been saved and the same conclusions reached as by means of the covariance method ; but if it is mistaken, they may well be fallacious.

It is advisable to investigate the variability of a calibration trial before laying down treatments. Detailed records should be kept from the time of planting, and these will indicate any likely sources of high variability, such as the presence of a few trees abnormally affected by drought or disease. At East Malling it is usual to work out the standard error of (a) *log* (trunk girth) in the preceding dormant season and (b) increment in *log* (trunk girth) over the last two growing seasons. If either is abnormally large, caution is needed in case some unusual source of variation is operating.

In the last two paragraphs references have been made to analyses of logarithms of egg counts and of trunk girths. The logarithms are used instead of untransformed data because here they are more nearly normal in their distributions (Pearce, 1943 and 1947).

II. Design of Orchards for Calibration Trials

General principles.

In order to save time, a research station may be well advised to plant orchards for future experiments as land becomes available and to calibrate the trees in readiness for the application of treatments. This has the disadvantage of forcing a decision upon varieties before the nature of the trial is known but, provided the choice is restricted to varieties which are commercially important and representative of distinctive classes, this need not be serious. In the rest of this Part methods of designing such orchards without prejudice to any of the different uses to which the trees may be put will be discussed. The discussion will assume that nothing is known about the treatments to come, but if the purpose for which the plantation is being calibrated can be forecast (e.g. spraying trials or manurial trials), the varieties, rootstocks, distance of planting, guard rows etc. can all be chosen appropriately and the design correspondingly improved.

It is often difficult to design an experiment upon given established trees though they may be ideal for the trial of some other set of treatments. Thus, the first consideration in designing calibration trials is *adaptability*, that is to say, provision should be made for any of a number of different kinds of trial, whether with many or few treatments, with or without guard rows. Special care should be taken to provide for the sorts of trial most likely to be needed. It is not easy to suggest any completely general rules, but certain broad principles will be stated below.

For calibration trials a " square " plant is to be preferred, triangular and quincunx plants giving low adaptability. However, the plant need not be exactly square, e.g. if a 14 by 16 ft. plant gives greater adaptability than one 15 ft. square, it may be used instead. In any event, irregularly shaped fields should be avoided whenever possible, nearly square ones being ideal.

Numbers of high and low adaptability.

It is most important that the number of plots that can be formed should have many factors, otherwise it is not easy to group the plots into blocks. To achieve this, it is found desirable to make each dimension* of a lay-out equal to some number with many factors plus two.

Consider some such dimension, say 26 trees. If guard trees between plots are not called for, it is necessary to exclude only the two outside trees. This leaves 24, a number that can be split up in several ways. If guard trees are needed, one of the 26 trees must be wasted to leave 25, but it is then possible to form 12 guarded plots each one tree wide together with their 13 guards, eight plots each two trees wide with their nine guards or whatever else is required. Such numbers can be said to possess *high adaptability*. Numbers like 15 or 19, on the other hand, are very awkward to split up whether guards are needed or not and can be described as of *low adaptability*. With a little practice it becomes quite easy to place any number in this scale of adaptabilities according to its potentialities in a calibration trial.

If the intention is to use several trees to a plot, it is usually sufficient that there should be enough of them to provide an experiment of reasonable size and that both dimensions should contain trees to an adaptable number. If one-tree plots are to be used without pollinators the position is no different, but one-tree plots with pollinators present some special problems.

Pollination.

First of all, suppose that pollination is to be provided by some second and subsidiary variety that is to have no part in the main trial. When this is so pollinators should as far as possible be assigned to outside rows, since these will be discarded anyway.

One tree in four of a different variety causes little reduction in adaptability apart from that due to the diminished number of trees available for the main trial. It should be noted that pollinators so disposed divide the trial into groups of three trees, so it is less necessary to provide for three as a factor of the number of plots to a dimension. Consequently numbers of trees like 18 and 34 become more attractive than they would otherwise be. One pollinator in six divides the trial into groups of five, but is otherwise satisfactory. One in nine, a common commercial practice, is very awkward if it is desired to make alternate rows guards.

A real difficulty arises, however, if several mutually pollinating varieties are to be included in the main trial with equal status. When this happens there is usually no need to randomize the varieties because there is no question of comparing them directly.† Sometimes only their interactions with treatments are needed, when it may in certain cases be assumed that the interaction of position and treatment is negligible and will not invalidate the testing of the interaction of treatment and variety with which it is confounded. Sometimes, especially in disease trials, several varieties are included but only one is expected to be of interest in respect of any particular disease. For laying out trials with several varieties two methods have been evolved, which will be alluded to as " stripe designs " and " tile designs ".

Stripe designs.

An example is afforded by the calibration trial on the left-hand side of Fig. 1. This consists of two stripes each four rows wide, separated by guard rows of pollinators. In each stripe, one row is assigned systematically to each variety.

When designing stripe trials, the number of stripes should either be small like two or three or, like four, six or eight, should have factors. The number of trees along a row should be of high adaptability.

* By *dimension* is here meant either length or breadth as measured by the number of trees contained. The *rows* of a trial will be considered to lie along its greater dimension.

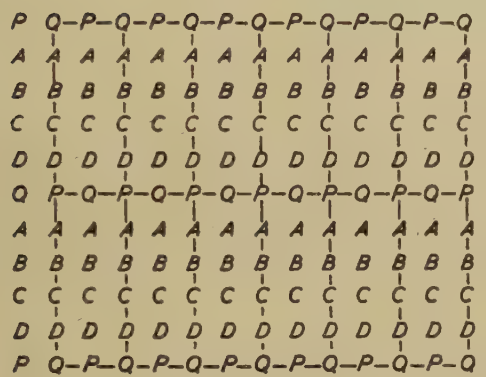
† In any event a separate analysis of covariance will be required for each variety, as the regression coefficients will almost certainly differ.

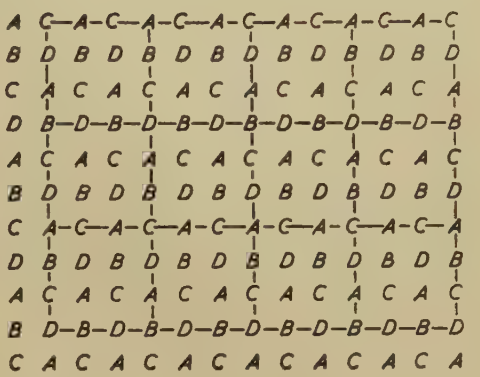
DESIGNS FOR CALIBRATION TRIALS.

STRIPE

TILE

1





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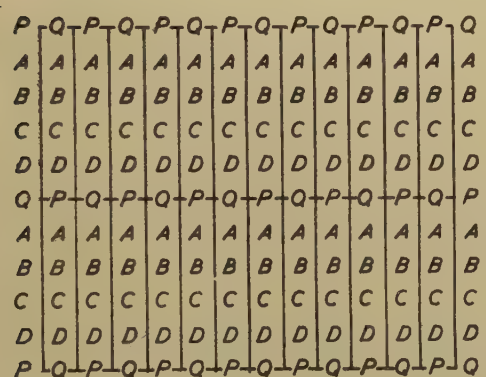

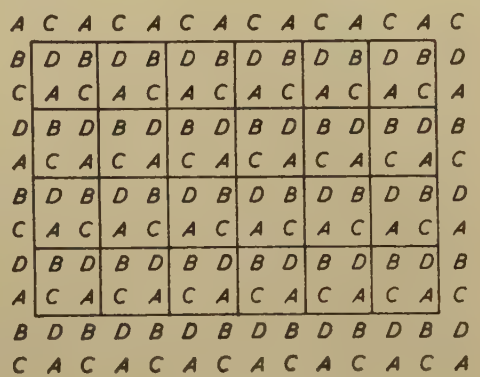

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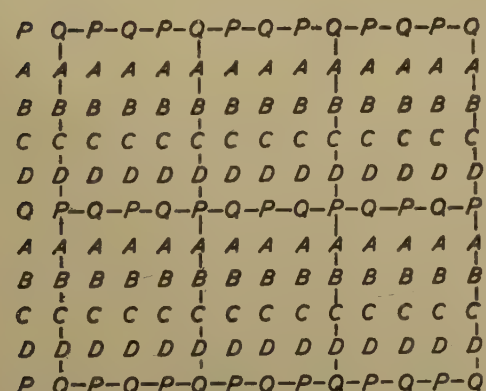

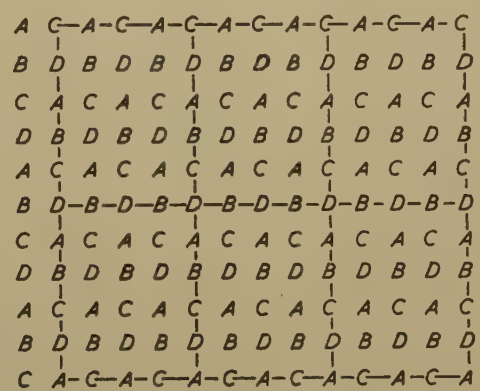

FIG. 1.

Types of planned calibration trials showing division into (1) guarded plots, (2) unguarded plots and (3) main plots each of three sub-plots.

Tile designs.

These designs are so called because each consists of a constant pattern recurring both along rows and across them like a floor made up of tiles of a single design. An example is given on the right-hand side of Fig. 1. In this diagram the 2 by 4 tree tile (Tile (i) of Fig. 2) first appears in the top left-hand corner. It is repeated across the diagram until it has occurred seven times. Downwards, one more row would be needed to give three repetitions.

To take the simplest case, if there are only two varieties a tile may look like this :

A	B
B	A

It will be seen that any plot of two trees anywhere in the trial must necessarily consist of one tree of A and one of B, whether the plot is taken along the rows or across them. Consequently, guard rows, if needed, may be introduced anywhere without disturbing the formation of plots—a fact that increases the degree of adaptability.

Similar designs are possible with more varieties and in Fig. 2 tiles are set out suitable for four varieties (i) and for six (ii and iii). With Tile (i), plots may be formed either of four trees across the rows or of four trees arranged two by two. However this is done, in any part of the trial, the plot thus formed will consist of one tree of each variety. Further, if a main plot is formed by guarding a rectangular area that contains an equal number of each variety, the trees of any variety within a main plot have the same position relative to one another as those of any other variety and, consequently, sub-treatments may be randomized upon the varieties within a main plot to give a valid split-plot design.

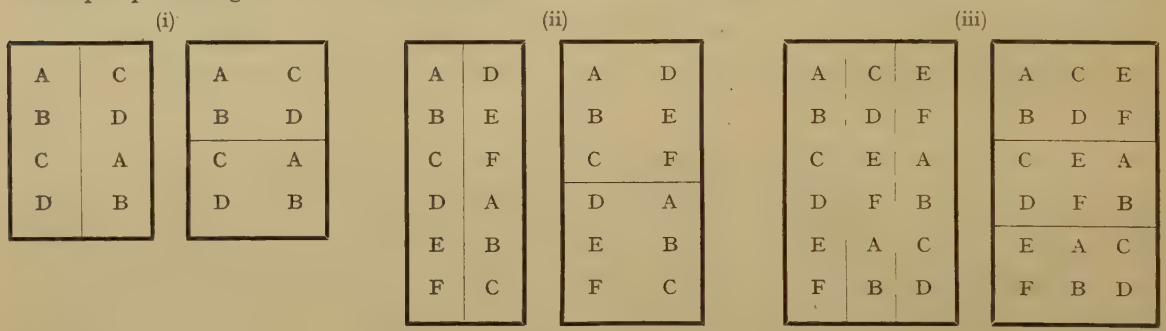

FIG. 2.

Tiles for four and six varieties. The short side of the tile should be parallel to the long side of the trial, i.e. rows in this diagram run horizontally.

Tiles (ii) and (iii) are possibilities for six varieties. With either, guard rows may be inserted as desired, but only with (ii) are valid split-plot designs available in the general case.

It should be emphasized that the plot boundaries shown in Fig. 2 are not the only ones possible and that a plot does not necessarily have to lie within a single tile. Each tile gives two methods of forming plots and the boundaries are intended only to illustrate those for each kind of tile. Fig. 1 shows the uses of Tile (i).

When designing experiments in tiles it is usually better to lay the long sides of the tiles parallel to the short side of the land, i.e. so that the length of the tiles lies across the rows and not along them. The number of trees in a row should be of high adaptability even though this will not always give an exact number of tiles. The best number of rows is not easily decided, but Table I sets out some suggestions that have been derived empirically by writing down each possible trial and testing its potentialities.

TABLE I.

SUGGESTED NUMBERS OF ROWS IN TILE CALIBRATION TRIALS WITH GIVEN NUMBERS OF VARIETIES

Number of varieties.	Tile.	Suggested numbers of rows.
2	–	4, 6, 8, 10, 14, 18, 26.
4	i	7, 11, 14, 19, 26.
6	ii	8, 15, 20, 26, 38.
6	iii	9, 15, 29, 38.

Relative advantages of stripe and tile designs.

Usually there is no need to make a choice because only one design is practicable. Thus, tile designs are available only for certain numbers of varieties while stripe designs can be used only when the number of rows is suitable. Fig. 1 illustrates the use of the two methods for four varieties in a set of trees 11 by 14.

In general, tile designs are often more adaptable and economical and are never less so. Stripe designs permit the introduction of additional varieties in the guard rows and so can ensure the pollination of an experimental variety that blossoms at a different time from the rest. Stripe designs are also easier to pick, though tiles are not as difficult as they seem if pickers always work along the rows and never across them. Also, as has been seen, stripe designs are better for split-plot experiments. Each type has its place and, indeed, they complement one another in a most useful way.

III. The Calibration of Commercially Planted Trees

In Parts I and II special attention has been given to trials planted for experimental purposes, but good use can often be made of trees planted commercially. For such trials calibration may be essential, unless there are many replicates. Since the history of such trees is generally unknown, their calibration must usually depend upon trunk girth or some similar characteristic. For apples, this is often enough, though Yeager and Latimer (1939) recommended waiting for two harvests before starting experiments so that calibration could be based upon crop. The decision must in any event depend upon the particular species.

There are certain advantages in using commercial orchards, thus :

(1) More trees are available than is usual at a research station. For some trials, e.g. of orchard heating, large areas are essential.

(2) Pests and diseases are sometimes peculiar to a certain locality and can be studied nowhere else.

There are also some disadvantages :

(1) Unless there is a choice of sites, it may be necessary to use a plantation containing unsuitable varieties, or with an uneven method of planting.

(2) Variability is often high. This may be due to physical causes, such as mixed rootstocks, scion-rooting, damaged or diseased trees. Trees may be of different ages and a grower is unlikely to have recorded which of his trees are replants. The soil of some plantations is very variable ; pollination may be uneven. It is, therefore, especially necessary to evaluate variability, as recommended in Part I.

(3) It is less easy to make the best use of the trees, partly because of their distance from laboratories and from measuring equipment and partly because of the difficulty of controlling cultural operations.

(4) There is not full freedom in selecting treatments because the trees must not be damaged. New untried sprays or the complete absence of manures may be harmful. Few control (untreated) plots may be used in spraying trials lest the pest increases rapidly in them and seriously reduces crops. Hence a trial comparing accurately the controls and the spray treatments may be impossible.

(5) A grower will not have allotted the trees of each scion-rootstock combination at random to the field positions to be occupied by that combination. This may be troublesome if more than one batch of trees be used, but the difficulty will largely be overcome if the trees are calibrated by past performance.

Despite their disadvantages, such trials are often necessary and can yield important results. Trials should, if possible, take place on the research or experiment station ; but, if outside trials are used, previous calibration of the trees is especially desirable.

Summary.

It is recommended that experimental trees should be planted as soon as possible, even before treatments are decided upon, so as to obtain knowledge of individual potentialities before the application of treatments. By means of this preliminary " calibration ", the variability of results can often be reduced. The laying-out of orchards for calibration is discussed and descriptions given of two designs (the " stripe " and the " tile ") suitable for trials with several varieties. The calibration of commercially planted trees is also discussed.

Acknowledgement.

The writers are indebted to Mr. T. N. Hoblyn for valuable suggestions on the arrangement of the paper.

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Addendum

While this paper was in the press the writers' attention was drawn to a recent publication from the North Carolina Agricultural Experiment Station in which several of the above ideas are independently expressed. The paper is especially valuable in suggesting ways of calibrating plants when past records are not available. The reference is: Rigney, J. A., Morrow, E. B., and Lott, W. L. (1949). A method of controlling experimental error for perennial horticultural crops. *Proc. Amer. Soc. hort. Sci.*, **54**, 209-12.

THE INTERPRETATION OF UNIFORMITY TRIALS

By S. C. PEARCE

There recently occurred an opportunity to examine the yields of a large block of irrigated vines in the Argentine. These data, originally collected and examined by Covas and Christensen (1945), were brought to East Malling by Mr. J. R. Christensen and re-examined by him under the supervision of the writer. Certain results of this re-examination have already been published by Christensen (1948) in Spanish ; but, since the treatment of the data was in some respects novel, it seems worth while to comment on certain aspects additional to those discussed by Christensen.

The data represented yields from 2,500 vines arranged 50 by 50. Eliminating guard plants all round 2,304 were left, arranged 48 by 48, of which 109 were missing or not in bearing at the time of the recorded harvest. Plots were taken only along rows and were grouped into blocks of various sizes, the grouping being done so as to make blocks as nearly square as possible. A correction was applied by covariance upon the number of bearing plants per plot.

The results are all set out in Christensen's Table I, which shows coefficients of variability for plots of different size and for blocks appropriate to various numbers of treatments. This table is reproduced as Table I of this paper.

One unusual feature of this table is the working out of the results four times over, once each for 4, 6, 8 and 12 treatments. In examining the results of most uniformity trials in the past, the number of plants to a block has been regarded as constant, increase in postulated size of the plots being accompanied by reduction in the number of plots and, therefore, of treatments to a block. Thus, assuming blocks of seventy-two plants, for plots of six plants (i.e. twelve treatments) the uncorrected yields give a coefficient of 21.16 ; while, for the same sized block, plots of twelve plants (i.e. six treatments) give a coefficient of 14.57, an apparent reduction of nearly one-third. The reduction in the corrected yields from 17.52 to 12.05 is similar. However, doubling plot size involves not halving the number of treatments but doubling block size and the real coefficients for twelve-plant plots,

TABLE I.

COEFFICIENTS OF VARIABILITY (EXPRESSED AS PERCENTAGES) FOR PLOTS AND BLOCKS OF VARIOUS SIZES.

	Uncorrected by covariance.				Corrected by covariance.			
Number of treatments.	4	6	8	12	4	6	8	12
Size of plot, 6 × 1 ..	17·49	18·58	19·13	21·16	15·55	15·80	16·96	17·52
,, ,, 8 × 1 ..	16·69	17·61	18·03	20·05	14·26	14·47	15·04	15·59
,, ,, 12 × 1 ..	13·45	14·57	15·22	17·76	11·13	12·05	12·72	14·49
,, ,, 16 × 1 ..	11·83	13·28	14·12	16·63	9·72	10·57	10·97	12·04

found by following down the column for twelve treatments, are 17.76 for uncorrected and 14.49 for corrected yields. The real reduction is, therefore, more of the order of one-sixth. This factor should always be taken into account when computing the results of uniformity trials, a point often overlooked in the past.

Christensen, on the basis of Table I, recommended the use of large plots of 12-16 plants. The question of plot size can well be considered, from the point of view of economizing land, as follows : suppose a trial were being designed with irrigated vines to show a significant difference (P = 0.05) of 20 per cent., there being four treatments. On the basis of Table I it would be necessary to use either 6.1 replicates of eight-vine plots or 3.1 of sixteen-vine plots,* but either way about 192 vines would be needed apart from guards. If, however, there were twelve treatments the choice would lie between 8.8 replicates of the smaller plot or 6.1 of the larger, so the eight-vine plot would be much more economical of land. These figures are based on the coefficients of variability uncorrected by covariance, but much the same conclusions arise from the corrected figures.

* These figures are taken to equal $0{\cdot}22V^2$, where V is the appropriate entry in Table I. In effect, this assumes t^2 to equal 4·4.

It appears then that a general recommendation to use large plots is justified only where land is not limited and the maximum information *per plot* or *observation* is desired. Where land is limited and the level of information *per unit area* is of greater importance, the use of small plots combined with a higher degree of replication is desirable, provided the treatments are relatively numerous. Where treatments are few, the same information in relation to area is obtained from large and small plots and it is more convenient to use large plots and few replicates.

These conclusions, based as they are on results from only one species, are possibly not of general application. It is clear, however, that optimum plot size for one purpose is not necessarily optimum for the other.

Summary.

Some general recommendations are made for the interpretation of uniformity trial data, arising out of an examination of the variability in the yields of irrigated vines in the Argentine.

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BIOCHEMISTRY

THE ORGANIC CONSTITUENTS OF THE APPLE TREE
PRELIMINARY WORK

By J. K. EATON*

A preliminary separation of the organic constituents of the apple shoot was found to be necessary in an investigation of the nature of the " immunity " of certain varieties of apple to attack by Woolly Aphid (Roach and Massee, 1931 ; Greenslade, Massee and Roach, 1934 ; Roach, 1937). In view of the interesting indications obtained, the work was extended to the leaves. The writer's work, done in 1938-39, is described fully in a thesis (Eaton, 1945). This note deals with a few of the more interesting facts that emerged from the work. The investigation has recently been extended using methods that have been evolved since the work now to be described was done (Bradfield and Flood, 1950).

Preliminary treatment.

Shoots.

Preliminary experiments had shown that at least one substance suffered rapid change unless special methods of disintegration and extraction were employed (Roach, 1932, 1937). This was a red material, later identified by Sir Robert Robinson as an anthocyanin, that occurred in some of the sub-epidermal cells of the shoot.

1.5 kg. of shoots formed during the previous growing season were cut from Allington Pippin apple trees on 18.4.39 and from Northern Spy trees on 11.5.39, and rubbed with a cloth to remove dirt. Each shoot was held in turn against a rapidly rotating tempered steel wire brush, described in detail elsewhere (Roach, 1950). This reduced the shoot to an almost impalpable powder which was delivered straight into absolute methyl alcohol held in an inverted bell jar. The latter formed part of a modified form of automatic low temperature vacuum extraction apparatus (Tattersfield and Roach, 1923 ; Roach, 1950). The powdered shoots were then completely extracted with methyl alcohol in this apparatus.

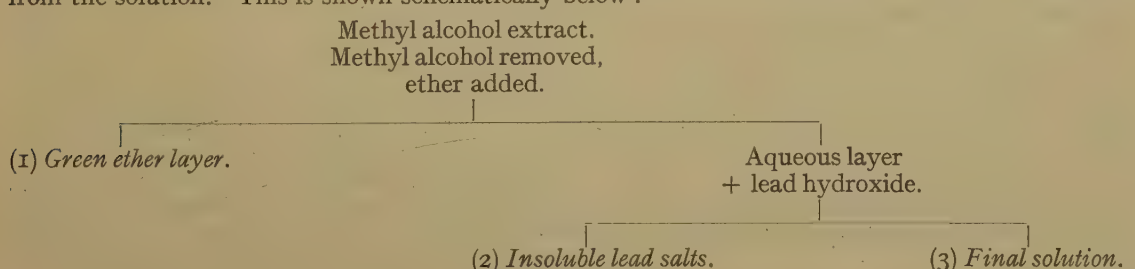
Leaves.

1·5 kg. of leaves were picked from Northern Spy apple trees on 11.8.38, and, after wiping with a clean dry cloth, were dropped into cold absolute methyl alcohol in the inverted bell jar. They became brittle almost immediately and were triturated with a long glass rod with a wide chisel-shaped end. The leaves were then completely extracted with methyl alcohol, using the low temperature vacuum extraction apparatus already referred to.

Preliminary fractionation of extract.

The chlorophyll-coloured extract was reduced in bulk by evaporation *in vacuo* until it separated into a deep red aqueous syrup and a dark green solid. Ether was added to dissolve the solid, and the red aqueous and green ethereal layers were separated from each other. The aqueous solution was washed with ether and the ethereal solution with water.

The red aqueous layer was treated with lead hydroxide and the insoluble lead salts were separated from the solution. This is shown schematically below :



The three main fractions will now be referred to in turn.

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Green ether layer.

Phloridzin.

The green ethereal solution was evaporated to dryness at 30° C. under reduced pressure. The dark green residue was extracted first with benzene, then with petroleum ether. The pale yellow residue was dissolved in ethyl alcohol and treated with a slight excess of lead hydroxide paste, and filtered. The yellow precipitate was used in tests for glyoxal referred to later. The filtrate was deleaded and allowed to evaporate in a warm place. A quantity of crystalline phloridzin (m.p. 110-112° C.) was obtained.

Lincoln (1926) showed that phloridzin occurred in the shoots, roots and leaves of the apple and the figures given are interesting :

PHLORIDZIN IN JONATHAN APPLE TREES.
Collected in the Autumn.

	Percentage on dry weight.
Leaves	8·8
Terminal half of shoots	5·7
Basal half of shoots	4·9
Main roots	11·7
Large roots	13·6
Medium roots	13·9
Wood from well-scraped branches	absent

Harvey (1925) pointed out that, in the apple, phloridzin is present in the highest concentration at the apex of the shoot and the amount becomes uniformly less towards the base. Lincoln's work mentioned above supports this. Harvey also stated that phloridzin was most abundant in apple shoots during early summer, the season of greatest metabolic activity, and that the maximum phloridzin content occurs one or two weeks later than the apparent maximum growth rate. Using a microchemical method, depending on the production of a red colour when phloridzin is treated with ferric chloride, Harvey (1929) claimed to have demonstrated that, in the cross section of an apple shoot taken in March, phloridzin was most abundant in the phloem, abundant in the outer cortex, scarce in the inner cortex, and occurs at or near the cambium. He also stated that when the buds are swelling in spring, the bases of axillary and terminal buds are extremely rich in phloridzin, which may amount to 15 per cent. of the dry weight of the stylar tissue.

In the present investigation the presence of phloridzin was proved in shoots of the varieties Allington Pippin, Northern Spy, Worcester Pearmain, Cox's Orange Pippin, Beauty of Bath and Laxton's Superb and of the Malling rootstocks Nos. I, II, III, IV, IX, XII and XVI. It was also found in leaves of the varieties Allington Pippin and Northern Spy.

The demonstration of phloridzin in large quantities in the shoots of at least thirteen varieties of apples, in the leaves of two and the roots of one variety establishes this substance as a major constituent of this plant.

Interference of phloridzin in sugar determinations.—Phloridzin is not precipitated by lead hydroxide nor by neutral lead acetate but it is precipitated by basic lead acetate. Unless basic lead acetate is used as a " clearing agent " before sugars are determined phloridzin is not removed from the solution. Van der Plank (1936), however, proved that basic lead acetate is unsatisfactory as a clearing agent because the precipitate is soluble in excess of the reagent. The use of dibasic lead acetate was suggested to reduce the solubility of the precipitated lead salt, but even with this reagent the precipitate was still appreciably soluble.

It became of interest, therefore, to determine how far the presence of phloridzin would interfere with the estimation of sugars by the usual methods. It was found that phloridzin is oxidized under the conditions normally used (Evans, 1928) for the oxidation and estimation of glucose in fructose-glucose mixtures and, moreover, that phloridzin gave a higher iodine value than glucose (2.367 compared with 1.404 for glucose). It was also found that phloridzin is partially hydrolysed by 10 per cent. citric acid under the conditions usual for the estimation of sucrose. Thus past estimations of glucose and fructose that took no account of the above facts are likely to be seriously misleading. This statement does not apply to the work of Leonard (1938), who extracted phloridzin with ether prior to estimating the sugars, which were proved by the writer not to be appreciably soluble in ether.

Glyoxal.

The yellow lead salt already mentioned above was treated with sulphuric acid and centrifuged. The yellow solution was boiled with dilute sulphuric acid and the reddish-brown solid formed was

removed. The filtrate was extracted first with ether and then ethyl acetate. The aqueous solution yielded a phenylosazone, m.p. 169·5° C., which may have been that of glyoxal, the m.p. of which is recorded as 177° C. Its estimated molecular weight was 225, and its nitrogen content 22·7 per cent., as against values of 238 and 23·5 per cent. for glyoxal.

Glyoxal was prepared by oxidation of acetaldehyde; and from this the phenylosazone was prepared. On purification, this melted at 174° C. This was mixed with the material melting at 169·5° C. and the mixture melted at 174° C. It seems likely, therefore, that the phenylosazone prepared from the plant extract was that of *glyoxal*. This substance bears an interesting relationship to the carbohydrates.

Insoluble lead salts.

Red anthocyanin.

Roach (1937) used a lead hydroxide method for isolating the laurel green salt, from which he released a deep red substance, identified by Sir Robert Robinson as an anthocyanin. The writer isolated a number of substances and fractions from the lead hydroxide columns but did not identify any of them.

A preliminary survey of shoots of different varieties by the lead hydroxide column method.

Preliminary unpublished work by Roach had revealed marked differences between varieties in the colour of the bands produced by allowing the aqueous fraction to percolate through a lead hydroxide column.

Preparation of the extract. Current year's shoots 40 cm. in length were cut and cleaned by wiping with a damp duster. 100 gm. of these shoots were disintegrated and shot into 400 ml. of methyl alcohol, contained in a beaker. After 2-3 hours the solution was filtered with suction and the residue washed with 300 ml. of fresh methyl alcohol.

The united alcohol extract was evaporated down to 15-20 ml. at 25° C. under reduced pressure, a green sludge being deposited on the walls of the flask. The concentrated aqueous extract was washed into a separating funnel by means of 10 ml. of distilled water and extracted with 50 ml. of ether. The ethereal layer was washed with 20 ml. of water. The combined aqueous layers were made up to 50 ml. with distilled water.

Preparation of the special lead hydroxide. Solutions of (a) 200 gm. of lead nitrate in two litres of water and (b) 80 ml. of ammonium hydroxide, d = 0·880, in two litres of water were heated to 63° C. and mixed by pouring simultaneously into a five litre beaker. The lead hydroxide settled after a few minutes and was washed thoroughly with water by decantation.

Preparation of the chromatogram. A slurry of lead hydroxide and water was poured into a glass tube (30 cm. × 1·3 cm.), plugged with cotton wool at the lower constricted end, until a column of lead hydroxide 10 cm. long was obtained. The rate of flow of water through the column with a head of 10 cm. of water, was 10-15 drops a minute.

The aqueous extract was run in, care being taken not to disturb the top layer of lead hydroxide. Coloured zones appeared as the liquid passed through the column. When all the extract had passed, the chromatogram was developed by treatment with 10 ml. of methyl alcohol. With each material examined duplicate chromatograms were prepared and found to be closely similar.

The appearances of the columns are indicated in Fig. 1. The widths of the bands are drawn to scale and the colours are described as in Ridgway's Colour Standards. It will be seen that the columns vary from one consisting of bands of different shades of yellow to one consisting mainly of green bands.

Examinations of the chromatograms. On examining a number of chromatograms, obtained from shoot material by the procedure described, the following points were noted:

(1) There are distinct differences between the chromatograms given by the rootstocks M.I, M.II, M.III, M.IV, M.IX, M.XII, M. XVI and the scion varieties Worcester Pearmain, Cox's Orange Pippin, Beauty of Bath, Duchess's Favourite, Allington Pippin, Northern Spy, Laxton's Superb and Bramley's Seedling.

(2) Two clones of rootstock, obtained during the selection of M.II, morphologically identical though anatomically distinguishable, and having different influences on the scion worked on them, gave identical chromatograms.

(3) Two specimens of the rootstock M.XVI, grown on fields about 500 yards apart, which prior to the planting of the rootstock had received somewhat different treatments, were found to give closely similar chromatograms (see Fig. 2).

(4) Chromatograms from shoots collected on 23.3.38 from two Cox's Orange Pippin trees grown on " no potash " plots were similar, though a little deeper in colour, to those from shoots of two trees of Cox's Orange Pippin receiving potash only (see Fig. 3).

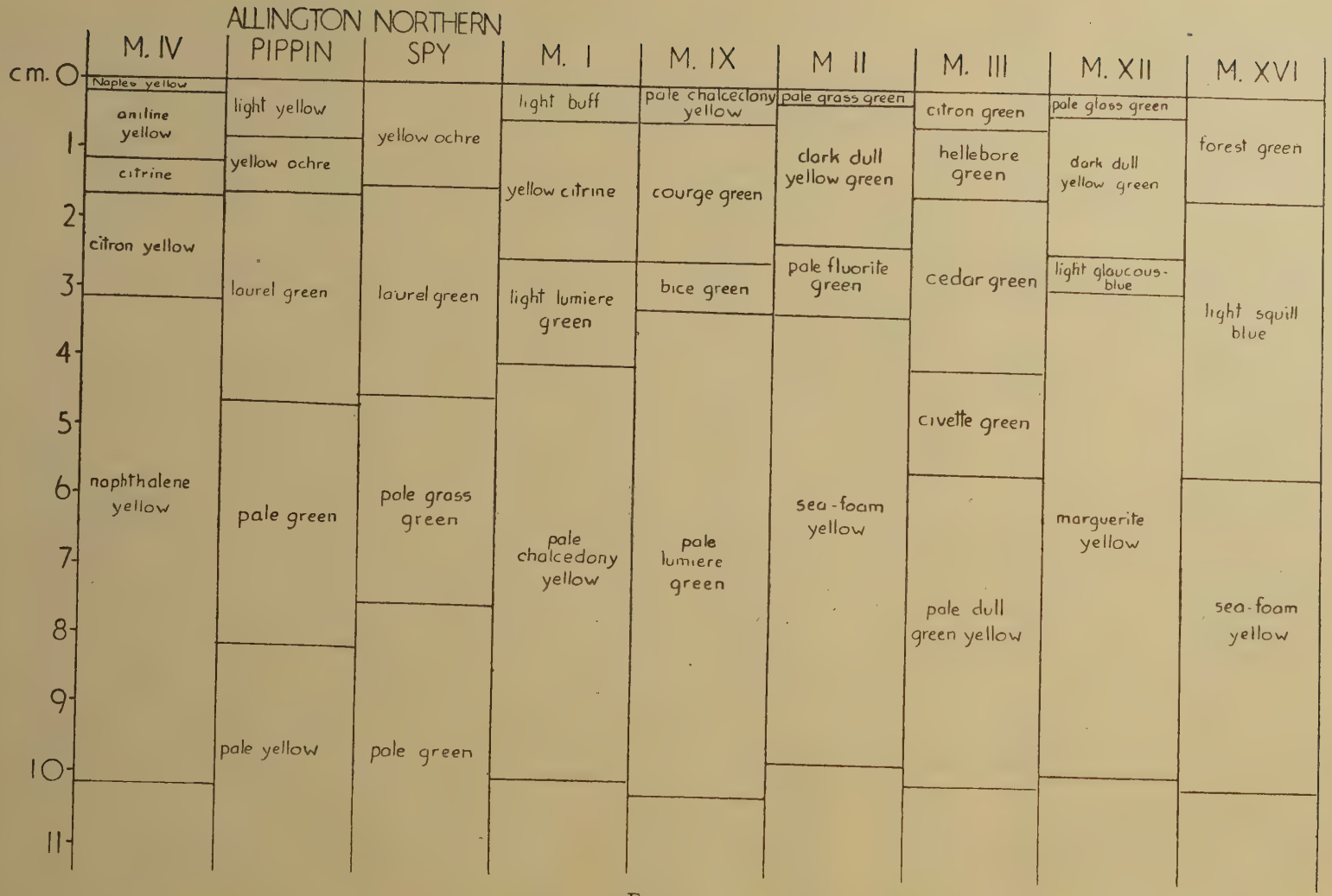

FIG. 1.

Descriptions of chromatograms prepared from shoots of different varieties of apple by the lead hydroxide method. Ridgway's Colour Standards were used to describe the colours of the bands, the lengths of which are indicated.

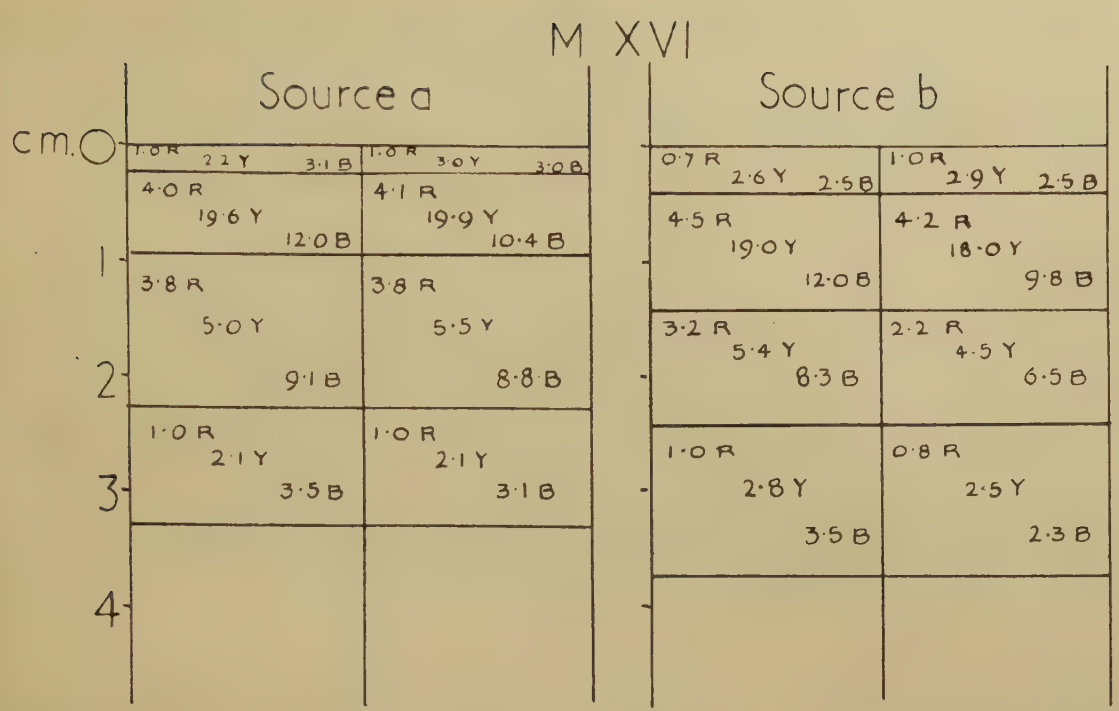

FIG. 2.

Chromatograms of shoots of rootstock M.XVI grown under different cultural conditions. Each chromatogram was prepared in duplicate. The colours were determined on a Lovibond Tintometer.

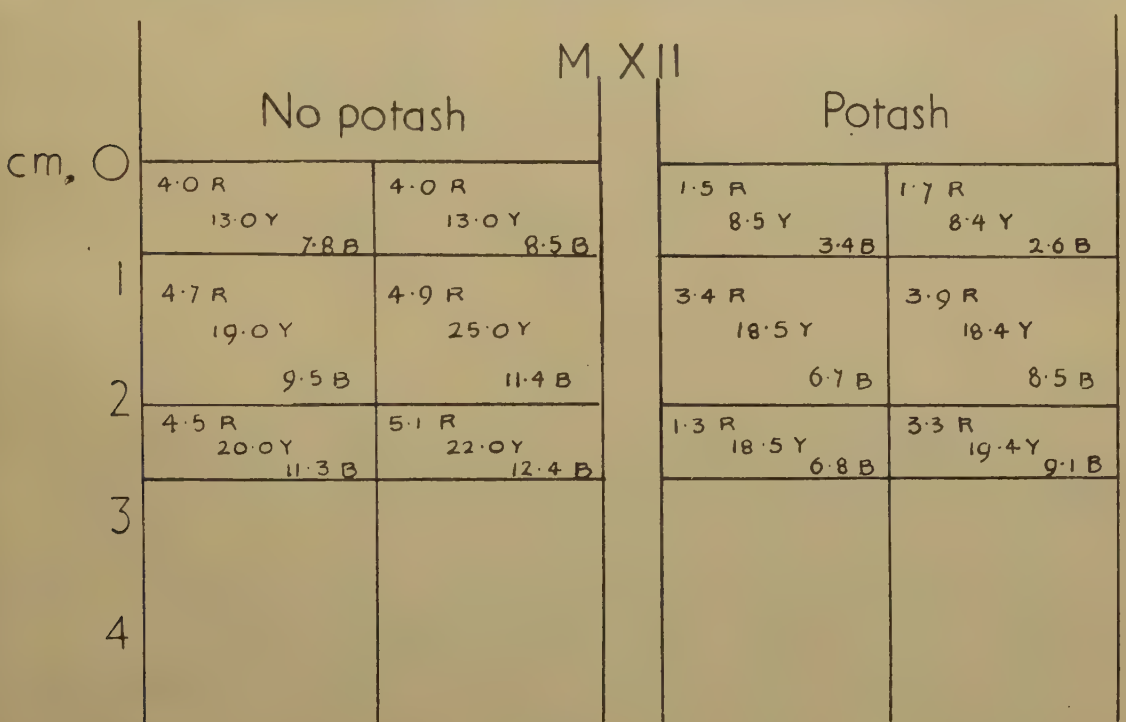

FIG. 3.

Chromatograms of shoots of Cox's Orange Pippin grown on plots receiving no potash and potash respectively. Those receiving no potash were a little darker in colour than those receiving potash.

(5) Prunings from Lane's Prince Albert apple trees on Malling rootstocks M.I, M.II, M.III, M.IV, M.IX, M.XII and M.XVI, cut on 30.1.39, gave chromatograms which were not appreciably different.

It may be concluded from these results that varieties of apples differ markedly in the substances that form insoluble salts with lead hydroxide.

Final solution.

Sorbitol.

Isolation and identification. 40 ml. of the filtrate from the lead hydroxide column were evaporated under reduced pressure at 30° C. and examined for the presence of sorbitol by the method used by Martin (1937) on the Bosc pear. After recrystallization from ethyl alcohol, the dibenzylidene compound melted at 180-181° C., both alone and when mixed with authentic dibenzylidene derivative of sorbitol. The melting point of the hexacetyl compound, prepared by the method of Tutin (1925), was identical with that recorded by Tutin, both alone and when mixed with authentic hexacetylsorbitol.

Estimation. On the basis of the yield of dibenzylidene derivative of sorbitol in the experiment quoted above, the sorbitol content of the shoots was calculated to be approximately 0·5 per cent. of the fresh weight, or 1·0 per cent. of the dry weight of the shoots. In control experiments it was established that no precipitate of a benzylidene derivative is formed by glucose under the conditions used.

Summary.

A preliminary examination was made of the methyl alcohol extract of the leaves and shoots of different varieties of apples.

A special machine disintegrated the fresh shoots and shot the powder into the alcohol. Fresh leaves were dropped into the alcohol. The extraction was done under reduced pressure at below laboratory temperature. Under these conditions certain labile constituents suffered little change.

Phloridzin was found in large quantities in the shoots of all fourteen varieties tested. The presence of phloridzin was proved to interfere with the determination of disaccharides and of glucose in the presence of fructose by the usual methods. This necessitates its removal by ether extraction.

Evidence was obtained suggesting the presence of glyoxal in the shoots. Sorbitol was proved to be present in shoots, of which it made up 0.5 per cent. of the fresh weight ; it formed an important constituent of the " carbohydrate " fraction.

The percolation of an aqueous fraction of the alcoholic extract of shoots through lead hydroxide columns gave a number of brightly coloured bands, which varied markedly from variety to variety.

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THE ORGANIC CONSTITUENTS OF FRUIT PLANTS

I. AN OUTLINE OF A METHOD OF EXAMINATION OF THE WATER AND ALCOHOL SOLUBLE CONSTITUENTS

By A. E. BRADFIELD and A. E. FLOOD

Introduction.

The co-operation of the organic chemist is desired on a number of problems in fruit growing. Preliminary work has already been done on the nature of the " immunity " of certain varieties of apples to Woolly Aphid (Roach and Massee, 1931 ; Roach, 1932, 1937 ; Greenslade, Massee and Roach, 1934 ; Eaton, 1945) and a start has been made on the study of the chemical basis of resistance to Bacterial Canker. Knowledge of the organic chemistry of the plant would also be of great value in the study of Apple and Pear Scab, growth substances produced by the plant, biennial bearing, incompatibility, mineral nutrition and frost resistance.

In the earlier work on apple varieties in relation to resistance to Woolly Aphid, the residues left after extraction of apple shoots with various solvents, when incorporated in food media for the insect, showed the same kind of differences in feeding value as the trees from which the shoots were obtained. The length of life of the insects, however, on such media was only a small fraction of that on the living trees. This suggests that some essential foodstuff had either been destroyed or removed during extraction. On the other hand, the extracts from shoots of both resistant and susceptible trees were toxic to the insects. The toxic material may have been extracted from tissues not used as a source of food by the insects or it may have been formed during extraction.

For the further study of this problem it is clear that a method for the systematic separation of the plant extracts into fractions is needed which will permit the rejection of the poisons common to both resistant and susceptible varieties while the essential food substances are retained and, further, which may lead to the isolation of any components peculiar to resistant or to susceptible varieties. This systematic investigation of plant constituents will also be necessary in the initial chemical attack on most problems of the types mentioned before a decision can be taken as to which types of compound require detailed study in connection with a specific biological problem.

Although a wide variety of organic substances has been found in plants, our knowledge of the chemical composition of the leaves, shoots, etc., of plants remains in every case incomplete and in most cases, rudimentary. This is so even with regard to the substances of comparatively low molecular weight, such as the carbohydrates, glycosides, plant acids, etc., which may be extracted from plant material with water or alcohol.

The first essential step in the chemical examination of the complex mixture of substances found in an aqueous or alcoholic extract of plant material is to separate the individual compounds. In particular cases one substance or, more rarely, two or three substances, may be isolated by comparatively simple *ad hoc* methods. For example, the glycoside phloridzin is readily obtained from extracts of the tissues of apple trees and has, in consequence, been known for about a hundred years. Nevertheless, general methods of separation likely to give a reasonably complete picture of the composition of a plant extract have hitherto been completely lacking.

In an attempt to fill this gap in our knowledge, an investigation has been begun of the simpler constituents of plants, particularly fruit plants, making extensive use of modern techniques. In the following a preliminary account is given of a general method of separating the water- or alcohol-soluble substances extracted from plant material into main fractions, and of chromatographic examination of these fractions. Although the chromatographic work is still in the early stages, it has already provided some new and interesting information, particularly concerning the soluble carbohydrates of the plant.

Method of preparation and fractionation of plant extracts.

Shoots were disintegrated and percolated with methyl alcohol at a low temperature in the apparatus described by Roach (1950). The bulk of the methyl alcohol was removed by distillation under reduced pressure and the aqueous liquid poured off from the green sludge (*chlorophyll fraction*).

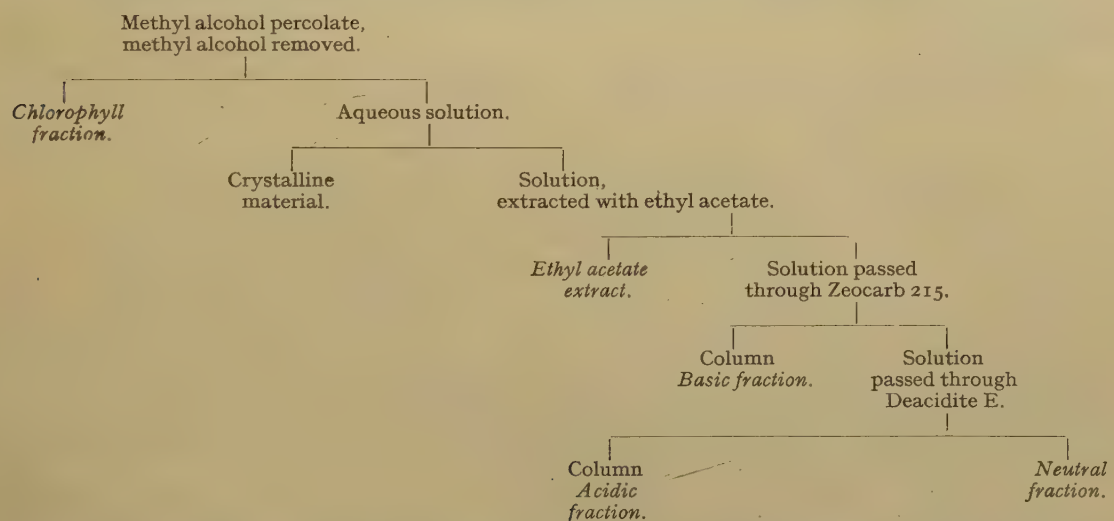
The aqueous solution was filtered from any precipitate which formed on standing (e.g., crude phloridzin in the case of extracts of apple shoots) and subjected to continuous extraction with ethyl acetate, the solution in the boiler being removed at intervals and replaced by fresh solvent. The time required for complete extraction varied from about 70 hours, in the case of apple shoots, to about 550 hours with pear shoots. In the latter case, the prolonged extraction is necessary to remove arbutin, which separates nearly pure from the later extracts. The ethyl acetate extracts were finally combined and evaporated, yielding, in general, resins which broke up in to amorphous powders. Such materials are referred to below as *ethyl acetate extracts*.

The aqueous liquid after ethyl acetate extraction was freed from dissolved solvent by distillation under reduced pressure and, after dilution, passed successively through columns of cation exchange resin (Zeocarb 215) and anion exchange resin (Deacidite E). The solution emerging from the last column was neutral and is referred to below as the *neutral fraction*. When the original solution contained anthocyanin the acid solution emerging from the cation exchange column was at first free from red colour, the anthocyanin having been held on the resin. Later the emerging solution was red. It has not yet been found possible to recover unchanged that portion of the anthocyanin retained by the resin.

When all the original solution had been passed through the two resin columns, the cation exchange column was washed with dilute ammonium hydroxide to displace any basic organic material held by the resin. Subsequent evaporation of the ammonia left only a small residue which was tested for amino acids with ninhydrin. No further examination of this *basic fraction* has yet been made.

The anion exchange column was washed with dilute hydrochloric acid. The organic acids and, in certain cases, phenolic substances, retained on the column, were displaced by the hydrochloric acid and an *acidic fraction* collected. The later portions of this fraction contained some chloride ion. Experiments are in progress to determine whether formic acid would be more suitable than hydrochloric acid for displacement.

The separation of the various fractions is summarized in the following scheme :



Leaves were extracted and separated into fractions by similar methods. Alternatively, the original plant material was extracted with boiling water, the extract being subsequently treated as above.

Chromatographic examination.

The fractions obtained as described above have been submitted to chromatographic examination on paper and on columns of cellulose and of silica gel. The paper chromatograms were run at room temperature by the descending method in glass tanks fitted with polythene troughs (at present no constant temperature chamber is available). No. 1 and No. 54 Whatman's filter papers were used. It is often an advantage to use the latter paper when good separation of slow running spots is to be secured by over-running. The solvents generally employed were butanol-acetic acid-water (Partridge, 1948), butanol-ethanol-water (Partridge, 1946), ethyl acetate-acetic acid-water (Jermyn and Isherwood, 1949).

The papers were examined in ultra-violet light before and after exposure to ammonia vapour and sprayed with appropriate reagents for the detection of the spots on the finished chromatograms. When further examination of material isolated on a paper chromatogram was necessary, the material was removed from the paper by the method of Dent (1947).

Paper chromatography is invaluable for the rapid examination of very small quantities of material, but in the present work the many unknown substances which have been detected will require isolation is greater quantities before the detailed chemical investigation required for their identification can be carried out. For this purpose column chromatography is, in general, more suitable.

The cellulose for use as column material was either prepared in the laboratory from Whatman's ashless filter tablets by rubbing through a sieve, or was one of several specimens of cellulose powder kindly provided by Messrs. Reeve Angel & Co. Ltd. The silica gel was prepared by the method described by Bradfield *et al.* (1947, 1948).

A variety of solvents have been employed. The use of columns has revealed that some of the proximate fractions mentioned above are even more complex than appears when they are examined on paper, but good progress is being made in the development of a procedure for their complete separation into their constituents. This part of the work will be dealt with in subsequent reports.

Results.

The results briefly outlined below are to be regarded as preliminary and are given only as illustrations of the value of the new techniques in this field of plant biochemistry. The plant material has been collected at various times during the year and no account has yet been taken of probable seasonal variation. The present work is qualitative and exploratory. For the purpose of studying the factors affecting the composition of the various fractions, it will be necessary to develop quantitative methods of estimation. This will be undertaken as soon as possible. The ethyl acetate soluble fractions still require an extended qualitative examination before quantitative work can be undertaken.

Carbohydrates.

Examination of the "neutral fraction" from shoots of apple rootstock 411, collected in December, 1948, revealed the presence of the carbohydrates shown below (Bradfield and Flood, 1950).

Pentoses :	None
Monosaccharides :	fructose, glucose
Disaccharides :	sucrose
Trisaccharides :	raffinose
Tetrasaccharides :	stachyose
Hexitol :	sorbitol

Much work has been carried out on the estimation of the carbohydrates of the apple, particularly of those occurring in the fruit, though little has been published on the identification of the sugars present. Eaton (1945) quotes a private communication from Archbold describing the identification of fructose and glucose. Partridge (1948) describes the identification of fructose, glucose and sucrose in the juice obtained from Bramley's Seedling apples.

The presence of raffinose and stachyose appears to have been hitherto overlooked although the amounts present are comparable with those of the more familiar sugars. As these two sugars can be regarded as sucrose combined with one and two molecules, respectively, of galactose, the absence of free galactose is noteworthy. It will be recalled that galactose has been found (Sando, 1937) as the sugar moiety of the pigments idaein (cyanidin-3-galactoside) and quercetin-3-galactoside in the skins of Jonathan and Winesap apples.

Sorbitol was isolated from apple juice by Tutin (1925), while Strain (1937), states that it occurs in small amounts in the leaves of apple, pear, peach, apricot and cherry. Eaton (1945) showed it to be present in quite considerable amounts in apple shoots, an observation which we have confirmed. Treboux (1909) has recorded that leaves of *Rosaceae*, which have been deprived of their starch by being kept in the dark, produce starch when floated on nutrient solution more readily from sorbitol than from glucose. This observation may provide a clue to the role of sorbitol in the metabolism of the plant.

It is of interest that the carbohydrate fractions of shoots of Myrobalan B and Brompton rootstocks and of Conference pear prunings, contain the same constituents as given above for the apple rootstocks. On the other hand, no raffinose or stachyose was found in a sample of Conference pear leaves gathered in the late autumn.

In view of the close similarity between the carbohydrate fractions of the various fruit plants (*Rosaceae*) it was thought that it would be interesting to compare them with a plant from a different family. For this purpose, wheat (*Gramineae*) was selected as being very widely different, and a carbohydrate fraction was isolated in the same manner from green Squarehead wheat stalks gathered in July. On chromatographing on paper, this material gave spots corresponding to fructose, glucose and sucrose, but in place of raffinose and stachyose four or possibly five spots were observed lying closely together, and to some extent overlapping each other. None of these corresponded to raffinose. In view of the small degree of resolution of these tri- and tetra-saccharides, it is uncertain whether one spot corresponded to stachyose. A sugar alcohol was also present.

Acids.

The identification of the plant acids by older methods has always been a matter of some difficulty. Employing the paper chromatographic method of Lugg and Overell (1947) the presence of citric, malic and tartaric acids has been readily demonstrated in the shoots of the apple rootstock 411 and the two plum rootstocks mentioned above. Oxalic acid, if present as the calcium salt, would not be extracted by our methods and was absent from our extract. Faint indications of one or two additional acids were also obtained, but these have not yet been identified.

Ethyl acetate soluble fraction.

So far as the carbohydrate fraction and the citric-malic-tartaric acid fraction are concerned, qualitatively there is little difference between the apple, pear and plum extracts so far examined.

In striking contrast, the ethyl acetate soluble fractions from apple, pear and plum shoots show little resemblance to each other. In each a complex mixture of substances is present but the " patterns " revealed by paper chromatography are very different.

By the combined use of silica gel and cellulose column chromatography and of paper strip chromatography certain of the substances have been separated and identified, for example, phloridzin, *epi*catechin and a quercetin arabinoside from apple shoots, but discussion is deferred until more complete knowledge is available.

Summary.

A method is described for the examination of the water- and methyl alcohol-soluble constituents of plant material isolated by percolation of the disintegrated material with cold methyl alcohol.

By concentrating, extracting with ethyl acetate, and passage of the solution through ion-exchange columns, a " chlorophyll fraction ", an " ethyl acetate extract ", and " basic ", " acidic " and " neutral " fractions are obtained. These are subjected to chromatographic examination on paper and on columns of cellulose and silica gel. In this way fructose, glucose, sucrose, raffinose, stachyose, sorbitol, citric acid, malic acid, tartaric acid, phloridzin, *epi*catechin and a quercetin arabinoside have been identified in an apple rootstock (411). The same carbohydrates and acids and sorbitol are found in Myrobalan B and Brompton rootstocks, and in Conference pear prunings. Leaves of Conference pear in late autumn contained no raffinose or stachyose. A preliminary examination of green Squarehead wheat stalks shows a more complex mixture of oligosaccharides to be present. In contrast to the carbohydrate and acidic fractions, the ethyl acetate extracts of the apples, pears and plums differ widely in composition. They are under examination and will be more fully reported on in due course.

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A FLAME METHOD OF SPECTROGRAPHIC ANALYSIS

By F. H. VANSTONE and H. J. PHILCOX

There are two general methods of flame spectrographic analysis available : the sample can be fed into the flame in solid form or it may be dissolved and the solution sprayed into the flame. The solution spray method was worked out originally by Lundegardh (1934), whilst the Ramage (1929) method, in which a filter-paper spill carrying powder or a dried solution is fed by hand into the flame, was the forerunner of the modern " solid " methods.

Roach (1946) effected considerable improvements in both sensitivity and accuracy of the Ramage method by distributing the powdered plant material evenly over the length of spill burnt, by fixing the point of introduction of the spill into the flame and by feeding the spill, by means of a synchronous motor, at a controlled and reproducible speed.

When both the Roach and Lundegardh methods have been applied to the same samples, while the order of accuracy has been the same, the Lundegardh method has required much the larger quantity of material. In the Roach method there is no elaborate preparation or chemical treatment of the sample, of which 25 mg. suffices, and so there is less risk of contamination, whilst the digestion and chemical treatment of the sample, upon which much work is still being carried out, require greater precautions to prevent contamination in the Lundegardh method.

In some biological problems the amount of sample available is often of the order of 10 mg. and sometimes less. Since the sensitivity of the Lungdegardh method is quite inadequate for this type of work, it was decided to develop the Roach method to give still higher sensitivity.

The determination of copper in plant material, where it occurs in the order of 5-10 p.p.m., by means of the arc, is complicated by the presence of copper in the carbon electrodes, frequently of the same order of concentration as in the sample. In the flame spectrum the copper lines 3247 and 3274 occur in the region where the flame background is very nearly at its heaviest. Any reduction in the time taken to burn a given weight of sample reduces the density of the flame background and should make it easier to detect the copper lines.

Again, the intensity of the light given out by the amount of some elements present in 25 mg. of plant material in the forty seconds of the Roach method is below the threshold intensity to which the photographic plate responds. If the sample were burnt more quickly and the total quantity of light given out by each element remained the same then it would be possible to raise the intensity of the light from such elements above the threshold value and enable the lines of these elements to be recorded on the plate. It, therefore, seemed that a considerable increase in sensitivity might be obtained by presenting the sample to the flame in a much more concentrated form than was practicable with the Roach method.

In the final form of the Roach method 25 mg. of finely ground plant material was distributed over a length of 2.5 cm. of the spill and fed into the flame in forty seconds. In this way the following minimum concentrations could be detected :

Potassium	.02 per cent.	Copper	20 p.p.m.	Manganese	2 p.p.m.
Iron	20 p.p.m.	Magnesium	10 p.p.m.		

It was attempted to retain the spill as the vehicle for carrying the sample because of its particular suitability for routine work, but no satisfactory method was found for making up spills with the plant material, or its ash, occupying lengths as little as 5 mm. or less, to give reproducible spectrograms. It was decided eventually to make up the sample in a tube of circular cross section.

In the method now to be described 15 mg. of the plant material is pressed into a length of 4.5 mm. in a cellophane tube 2.5 mm. in diameter and 1 cm. long, the remainder of the tube being filled with cellulose powder, supplied by Messrs. Reeve Angel and Co., Ltd., containing negligible quantities of sodium, potassium, calcium and iron. When fed into the flame, the greater part of the sample is volatilized near the middle of the flame in less than eight seconds.

This method enables the concentrations and amounts shown in the following table to be detected with ease.

TABLE SHOWING AMOUNTS OF VARIOUS ELEMENTS DETECTED BY THE FLAME METHOD USING DIFFERENT SLIT WIDTHS AND PHOTOGRAPHIC PLATES.

	Chromatic plate.				Zenith plate.			
	Slit 0·02 mm.		Slit 0·04 mm.		Slit 0·02 mm.		Slit 0·04 mm.	
	Concentration (p.p.m.)	Total amount (g)	Concentration (p.p.m.)	Total amount (g)	Concentration (p.p.m.)	Total amount (g)	Concentration (p.p.m.)	Total amount (g)
Copper	1	$1·5 \times 10^{-8}$	0·5	$7·5 \times 10^{-9}$	0·5	$7·5 \times 10^{-9}$	0·25	$3·7 \times 10^{-9}$
Manganese	1	$1·5 \times 10^{-8}$	0·5	$7·5 \times 10^{-9}$	0·5	$7·5 \times 10^{-9}$	0·25	$3·7 \times 10^{-9}$
Iron	2	$3·0 \times 10^{-8}$	1·0	$1·5 \times 10^{-8}$	1·0	$1·5 \times 10^{-8}$	0·5	$7·5 \times 10^{-9}$

	Long-range spectrum plate.			
	Slit 0·02 mm.		Slit 0·04 mm.	
	Concentration. (p.p.m.)	Total amount (g)	Concentration (p.p.m.)	Total amount (g)
Rubidium	0·4	6×10^{-9}	0·2	$3·0 \times 10^{-9}$
Lithium	0·1	$1·5 \times 10^{-9}$	0·05	$7·5 \times 10^{-10}$

Description of method.

Formation of cellophane tube.

The apparatus used, shown in Fig. 1, houses two rolls of cellophane tape, 1 and 2, one of which, 1, has an adhesive face, and is the trade product known as Sellotape. The Sellotape and Cellophane tape are supplied uncontaminated, by Adhesive Tapes, Ltd. Initially, 1 is in the position shown in Fig. 1, with its adhesive face uppermost, and is retained in this position by the lever 3. When the rubber-faced roller, 4, is turned clockwise, cellophane tape 2 is fed towards and over the end of tape 1. When a sufficient length of tape 2 overlaps tape 1 the two are pressed together with a perspex rod and are joined at 5 (Fig. 1a).

Split pin 6 (Figs. 1a and 1b) is eased gently into position with its prongs parted, with tape 2 passing between the prongs. When the prongs of 6 are sprung together the tape is held firmly and it is cut with a razor, close to the pin 6. When 6 is turned anti-clockwise the tapes 1 and 2, joined together, are drawn around it and the roll of 1 unwound. Two turns of 6 provide sufficient of the adhesive tape free of 2 to adhere to the tape already drawn on to 6. The cylinder completed, tape 1 is cut close to it, leaving 1 in position for the manufacture of the next tube. Fig. 1b shows the cylinder in position on the split pin after tape 1 has been cut.

It is a simple matter to transfer the tube into the hole in perspex block 7, Figs. 2 and 3, for the filling operation. It is noteworthy that neither the tapes nor the completed tube are touched by hand either during the manufacture of the tube or in the subsequent operations in which the tube is involved. It should also be noted that both the inner and outer surfaces of the tube consist of cellophane with no uncovered adhesive surface.

When the tube is in position in 7, the diametrical piece of cellophane formerly held by the prongs of the split pin is nursed to the wall of the tube by the insertion of a rod of polished wood.

Method of filling cellophane tube.

The apparatus used is shown in Figs. 2 and 3, and is made of perspex with the exception of the spigot of rammer 8, which is of steel, heavily rhodium plated to prevent contamination.

Slide 7 is a perfect fit in the channel in block 9 ; and when 7 is pushed home the tube in 7 is then concentric with the funnel in 9. Positioning and dimensions of the cylindrical portion of the funnel must be within very fine limits and the components of each filling set must not be interchanged.

The slide 7, which is 1 cm. thick (the length of the tube), with the tube in position, is pushed into position in 9. A weighed amount, normally 15 mg. of the dry powdered plant material is poured into the polished funnel and tapped into the tube. The material is pressed to a length of 4·5 mm. by

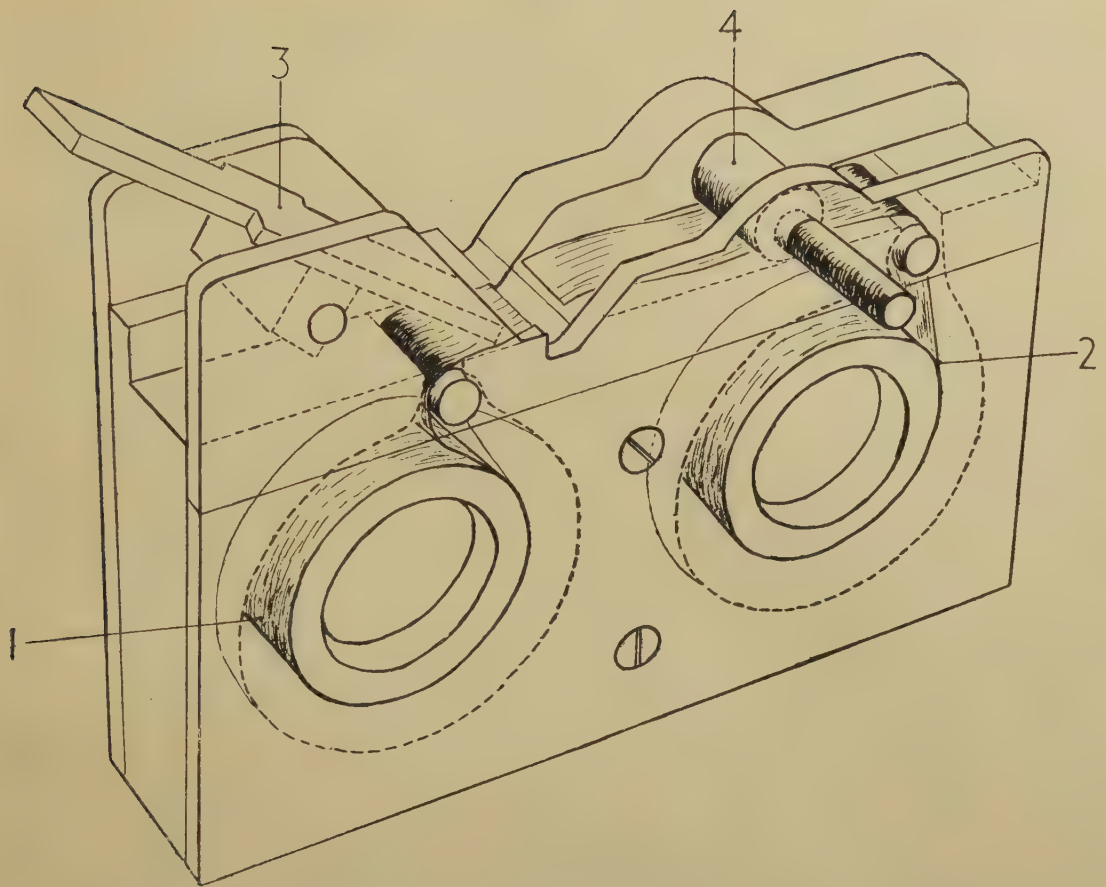

FIG. 1.
Tube forming unit. (1) Roll of Sellotape. (2) Roll of cellophane tape. (3) Positioning lever. (4) Rubber-faced roller.

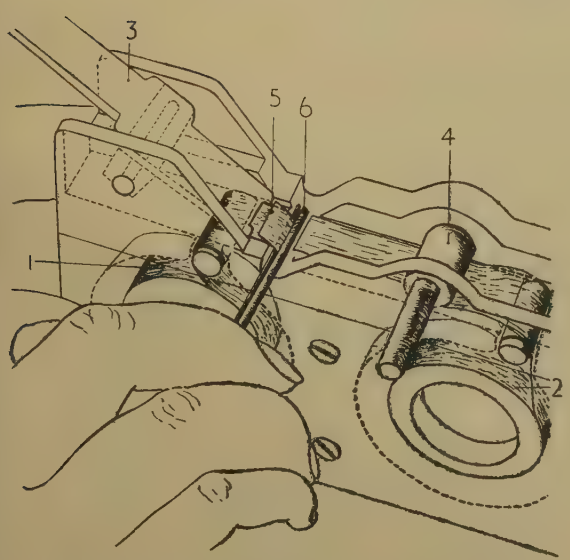

FIG. 1(*a*).
Tube forming unit showing intermediate stage in the formation of a tube. (5) Shows area of overlap of the Sellotape and cellophane tape. (6) Split pin around which the tube is formed.

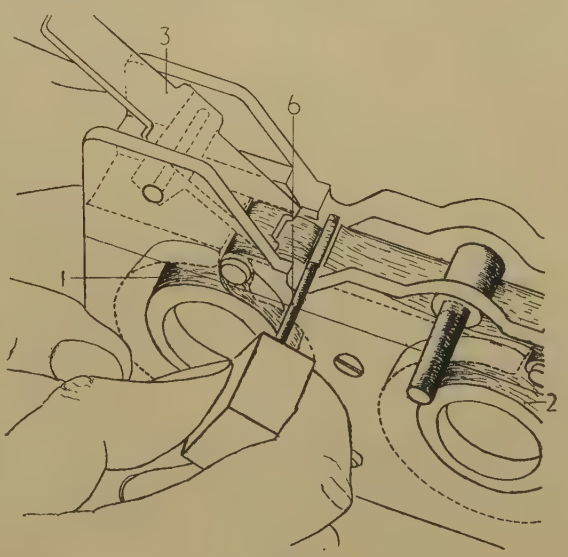

FIG. 1(*b*).
Tube forming unit showing completed tube in position on the split pin.

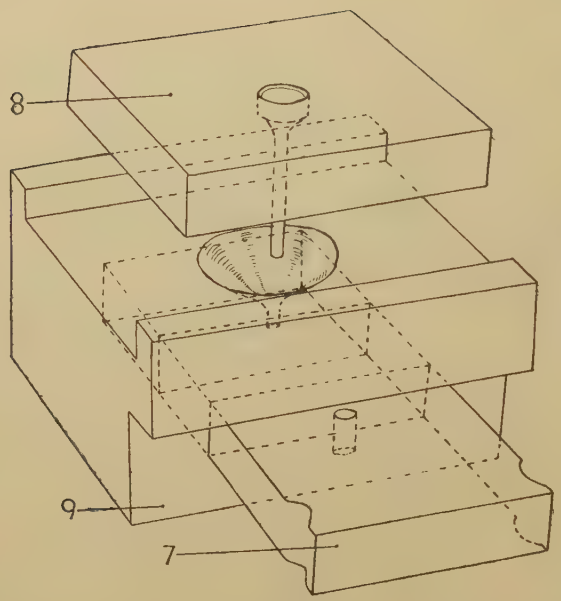

FIG. 2.

Pressing Mould. (7) Slide which carries the tube. (8) Ram. (9) Funnel and locating unit.

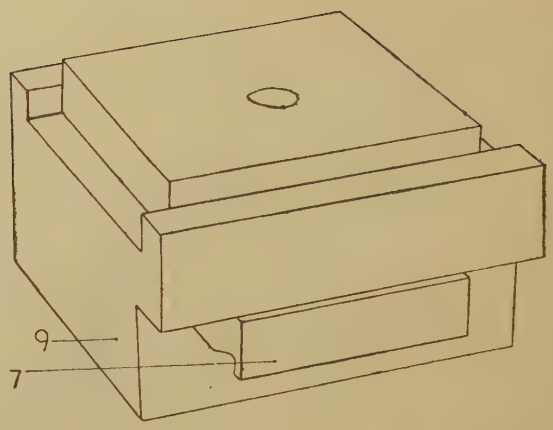

FIG. 3.

Pressing Mould. Slide, with ram in position in the locating unit for pressing the sample.

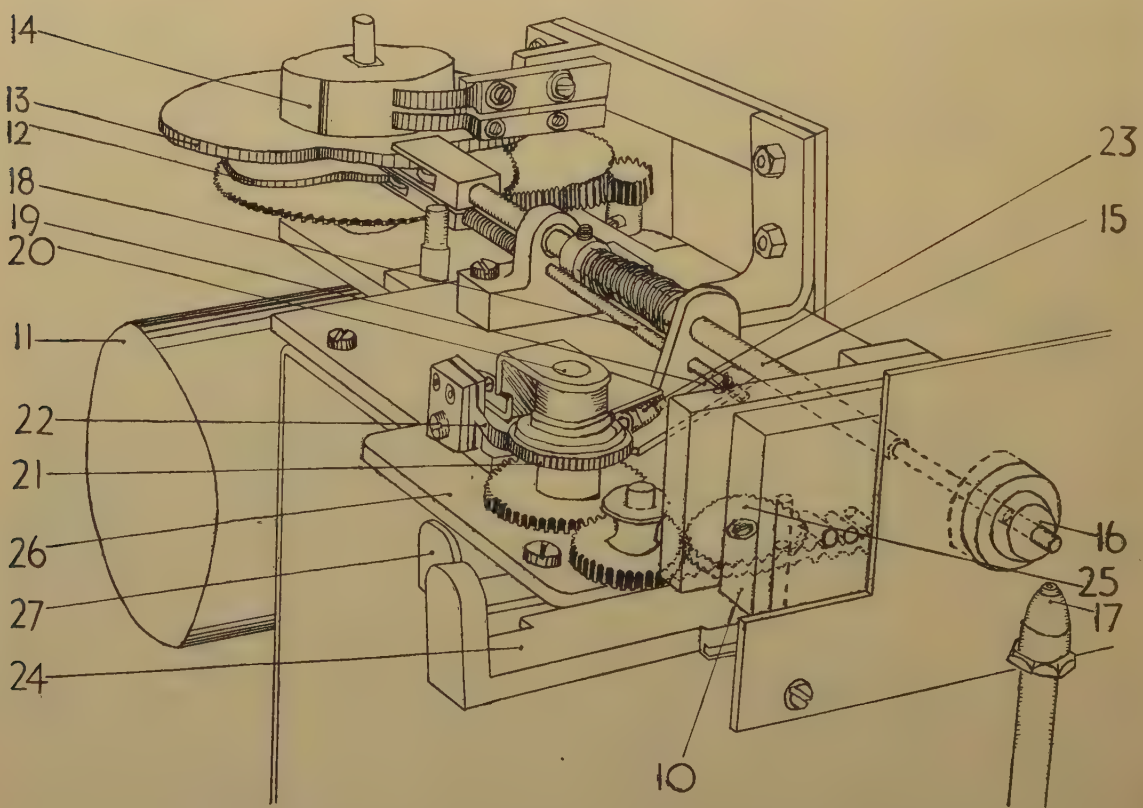

FIG. 4.

Feeder Unit. For description see text.

pressing the rammer 8 until the perspex portion of 8 rests on the top surface of 9, as shown in Fig. 3 ; hand pressure just suffices. Under these conditions the method of the formation of the sample pellet is reproducible and quite independent of any personal factor. The remainder of the tube is filled with " cellulose powder ", which is consolidated by hand stemming.

The filled tube is almost ejected from 7, by pushing the end remote from the sample with a wooden pusher, and finally removed in platinum-tipped forceps and placed in a hole in a perspex block containing twenty such holes for holding a series of filled tubes.

For burning, the tubes are inserted into the holes of the perspex magazine 10, which as shown in Fig. 4 has been inserted into the feeder unit.

Feeder unit.

The unit fits on, and can slide along, a bar attached at right angles to the accessory bar of the Hilger Medium Spectrograph. The whole unit can be moved along or across the axis of the spectrograph and vertically, and provision is also made for relative movement between the flame and the feeding mechanism in these three directions.

A 1/40 h.p. motor, 11, drives, through a gearing assembly, a vertical spindle carrying cams 12 and 13 and circular disc 14 at 4 r.p.m. The disc 14 carries two metal bars which in turn short across the contacts in the shutter electromagnet circuit and so open and close the shutter, the instant of opening and the time of exposure being controlled by the positioning of the bars. The rotation of cam 13 causes the spring-loaded ram 15 to move forward, pushing a filled tube in its path out of the magazine 10, into the flame through the graphite gun 16. The platinum tipped nozzle is shown at 17. The cam 13 is shaped so that the tube moves rapidly into the flame until the middle of the sample is in the middle of the flame, stays in this position for five seconds, and then the ram moves backwards.

The rotation of cam 12 controls the movement of the spring-loaded rod 18. As 18 moves forward the connecting rod 19 rotates around the spindle 20 in a clockwise direction. The toothed wheel 21 is prevented from rotating in this direction by the retaining ratchet 22 ; and so during the forward movement of 18 a ratchet, 23, attached to connecting rod 19 traverses three teeth of the wheel 21. During the backward traverse of 18 the ratchet 23 engages in a tooth and rotates wheel 21 through the angle occupied by three teeth. This rotation of 21 is translated through a series of toothed wheels and a final rack and pinion arrangement into a lateral movement of the magazine support, 24, and so of the magazine itself, bringing the next sample tube into line with the graphite gun 16. Cams 12 and 13 are arranged so that the rod 18 does not start its backward movement, which results in the movement of the magazine, until the ram 15 has disengaged itself from the magazine. The wheel 21 and the gearing assembly (apart from the last pinion 25) which it controls are housed on a separate platform 26. A spring between this platform and the main body of the apparatus loads the gearing assembly on to the final pinion 25. When the handle, 27, is pulled this assembly is released from the pinion 25 and the magazine can be moved to bring any desired hole in the magazine into line with the graphite gun 16.

The unit is capable of burning, without reloading of the magazine, a series of 10 samples at quarter-minute intervals, i.e. the ten samples in a total of $2\frac{1}{2}$ minutes.

The metal bars on disc 14 are arranged to open the shutter as the sample enters the flame and to give an exposure of eight seconds. The sequence in burning a magazine full of samples consists in placing the magazine in position with the first sample in line with the gun and switching on the motor. As the first tube traverses the gun the remainder of the tube from the previous burning is first ejected and then the first tube enters the flame, with its axis 4 mm. above the tip of the cone of the flame, as the shutter opens. When the shutter has closed, the photographic plate is racked by hand to its next position, the next tube moves automatically into position and the cycle is repeated. After the switching on of the motor the only manual operation involved in the production of the 10 spectrograms is the racking of the photographic plate between exposures.

Flame.

The burner is that used in the Roach method but the larger diameter of the cellophane tube, compared with the thickness of the spill, has required a new type of flame. When the tube was fed into the flame used with the spill method the flame was split, in an unpredictable manner, into two streams which wandered during the burning.

It has been found with this type of burner that over a small range of jet diameter the component of the inlet velocities of the gases in the plane of the inlet ports is apparently not entirely destroyed by the mixing process. This results in a flame of elliptic cross-section, the major axis being along the axis of the spectrograph. With a jet of diameter 0·048 in. the tube is fed with its centre 8 mm. above the jet at right angles to the axis of the spectrograph into an oxy-acetylene flame 10 mm. wide, the width of

the flame as seen from the spectrograph being 6 mm. When the tube is fed centrally into such a flame there is no splitting and the flame behaves in a perfectly reproducible manner. The condition is not very critical but if the feed is appreciably to either side of the flame, poor reproducibility results.

The oxygen is used at a pressure of 50 cm. of mercury and the acetylene at 1 cm., giving a flame 30 cm. in height. The flame is not very sensitive to draughts but a draught screen is used as a precautionary measure.

The short length of tube containing sample material involved has enabled the sample to be placed rapidly into position symmetrically distributed on either side of, and near to, the centre of the flame, so that the greater part of the sample is volatilized in the hottest portion of the flame.

Summary.

A largely automatic method of flame spectrographic analysis is described in which 15 milligrammes of dried, ground plant material is compressed in a cellophane tube of 2·5 mm. diameter and fed mechanically into an oxy-acetylene flame. With an exposure of eight seconds as little as 4×10^{-9} gm. of copper, manganese and rubidium can be detected with ease.

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THE ESTIMATION OF PHOSPHORUS, POTASSIUM, CALCIUM, MAGNESIUM, IRON, MANGANESE AND NITROGEN IN PLANT MATERIAL

By A. C. MASON

A full investigation of the mineral nutrition status of plants must take account of at least ten elements, i.e. the above seven and in addition copper, zinc and boron. These are essential for plant life and deficiencies of each of them are known to be of economic importance. Analyses for carbon, hydrogen, oxygen and sulphur are not normally required in nutritional problems. Other elements will undoubtedly require consideration in due course.

The aim of the work described has been to develop routine chemical methods which enable a full analysis for the ten elements listed to be carried out on the smallest possible sample with a precision of ± 5 per cent. This aim has not been realized yet, but this report describes briefly the methods which are in use at present, in this laboratory, as a means of comparing notes with other workers in this field.

The plant material, usually leaf laminae, is cleaned, dried in an oven at 80° C. and finely ground in an agate mortar. After reaching equilibrium conditions with the air, a convenient quantity is weighed out and this, the air dry weight, is taken as the basis for analysis. Where necessary, moisture content is determined by drying to constant weight at 100° C., and the analyses corrected. The sample of dry material is brought into solution by some convenient method and made up to a standard volume. Aliquots of this ash solution are then withdrawn for determination of the individual elements.

Preparation of the ash solution.

All the elements listed above, except nitrogen and potassium, are determined on aliquots withdrawn from a solution of plant ash prepared in the following manner :

200 mg. of dry material is weighed into a counterpoised aluminium scoop and transferred by brushing into a nickel trough prepared by bending a rectangular piece of sheet (50 mm. × 25 mm.) around a wooden former. The trough is pushed into a centrifuge cone of 10 ml. capacity with a fairly sharp point, which is then placed in a holder constructed from a rectangular silica plate and nichrome wire. A muffle furnace is brought to approximately 420° C., and the samples in their holders are heated at this temperature until completely ashed (approximately 1 hour). The holders are then withdrawn and cooled and the ash transferred from the trough into the point of the cone by up-ending and tapping. It is sometimes necessary to use a fine camel-hair brush to detach a few particles of ash which adhere to the trough. The trough is removed with forceps and 1 ml. of N hydrochloric acid added to the ash from a graduated teat pipette. When the reaction is complete, the contents of the tube are centrifuged. The clear liquid is transferred to a 2 ml. graduated stoppered flask (Fig. 1).

FIG. 1.
Graduated flask, 2 ml. capacity.

By means of a teat pipette a few drops of water are added to the residue in the cone, mixed well and transferred as completely as possible to a square of platinum foil, having a shallow depression about 20 mm. diameter, and in the centre a deeper depression about 7 mm. diameter. The solution is confined as far as possible to the centre depression and gently evaporated over a 60 watt electric lamp, or a beaker of boiling water. When dry, about 20 mg. of dry sodium carbonate is scooped into the centre depression and the whole ignited over a small bunsen flame until a clear melt is obtained. After cooling, the melt is extracted with N hydrochloric acid, transferred to the original centrifuge cone and centrifuged. The clear liquid is added to the original solution in the 2 ml. flask and the residue discarded. The ash solution is made up to the mark with water.

One operator can prepare eight samples in this manner in about four hours. The reason for the fusion is that the insoluble siliceous residue adsorbs, or combines with, considerable amounts of iron and boron ; also manganese may be present in an insoluble form. If, however, only P, K, Ca, and Mg are to be estimated the fusion is probably unnecessary. The low temperature of ashing and absence of local hot spots due to restricted air supply ensure that losses of these elements by volatilization do not occur.

Phosphorus.

0·2 ml. of the ash solution is pipetted into a 10 ml. graduated stoppered flask. To this are added, with shaking between each addition, the following reagents from quick delivery pipettes :

(*a*) 1·0 ml. of 20 per cent. w/v sodium sulphite crystals in water.

(*b*) 1·0 ml. of ammonium molybdate solution (25 g. cryst. ammonium molybdate in 300 ml. water to which is added with stirring 200 ml. of dilute sulphuric acid, prepared by diluting 75 ml. conc. H_2SO_4 with 125 ml. water).

(*c*) 1·0 ml. of 0·5 per cent w/v hydroquinone in water.

After making up to the mark with water and standing one hour, the coloured solution is " spekkered " in a 1 cm. cell using neutral, heat absorbing, and No. 608 spectrum filters. The drum readings for the solution and the blank are determined. The drum difference figure gives, by reference to a graph previously prepared from standard solutions, the phosphorus content of the plant material. A blank determination on all reagents is run concurrently with all determinations.

Potassium.

Until recently 0·1 ml. of the ash solution served for the estimation of potassium by precipitation of the sodium potassium cobaltinitrite complex. More uniform results have been obtained by precipitation of the silver potassium cobaltinitrite complex, which entails the absence of chlorides. The present procedure in this laboratory is to prepare a separate ash solution as described below. So far there has been no opportunity to check the general suitability of the nitric acid solution of the ash for the determination of the other elements.

0·2 g. plant material is ashed as described above except that only one centrifugation is carried out, the residue being discarded, and 0·5 ml. nitric acid is used to dissolve the ash instead of hydrochloric acid. The solution is made up to 2 ml. in a graduated stoppered flask with water.

0·1 ml. of the nitric acid solution is pipetted into a 15 ml. centrifuge tube and 4 ml. of acetate buffer added (40 ml. 0·2 N acetic acid and 60 ml. 0·2 molar sodium acetate). The pH of the buffer is 4·8. 0·5 ml. of 0·2 M silver nitrate is added and then 0·5 ml. of sodium cobaltinitrite suspension is slowly run in with vigorous stirring, using a small mechanical stirrer. (The suspension is prepared by dissolving 2·5 g. of sodium cobaltinitrite in 5 ml. of water and adding 10 ml. absolute alcohol slowly with shaking. After centrifugation, the supernatant solution is decanted and the precipitate suspended in 50 ml. of absolute alcohol. This should give a finely divided even suspension. The bottle should be shaken immediately before any reagent is withdrawn.)

The precipitate is centrifuged at 4,000 r.p.m. for 5 minutes. The supernatant liquid is removed by means of a teat pipette to avoid loss of the small amount of precipitate which often floats on the surface of the solution. 1 ml. of water is added and after mixing with the precipitate and re-centrifuging, the wash liquor is withdrawn with a teat pipette and discarded. 1 ml. of 2 N sulphuric acid is added to the centrifuge cone which is placed in a boiling water bath and the precipitate stirred until dissolved. After cooling, 6 ml. of thiocyanate reagent are added with stirring and the blue colour which develops immediately is " spekkered " after ten minutes in a 1 cm. cell using Ilford No. 601 and neutral filters. The thiocyanate reagent is made up by dissolving 5 g. ammonium thiocyanate in 40 ml. water and adding 60 ml. of acetone. The solution should be made up freshly and filtered before use.

A blank is run concurrently and the drum readings for the sample and for the blank are determined. The drum difference figures give, by reference to a graph previously prepared from standards, the potassium content of the plant material.

Calcium.

0·1 ml. of ash solution is pipetted into a 5 ml. beaker, 1 drop of 0·001 per cent. methyl red in water added, and the solution neutralized by adding 0·1 M sodium acetate from a teat pipette. The solution is brought to the boil and about 0·75 ml. of 2·5 per cent. ammonium oxalate solution is added.

The contents of the beaker are concentrated to a volume of approximately 1 ml. and then kept on a boiling water bath for half an hour. To ensure complete precipitation of the calcium oxalate it is advisable to stand overnight. The contents of the beaker are completely transferred by means of a teat pipette to a 1 ml. centrifuge cone and whirled for about 10 seconds in a hand centrifuge. The liquid is removed by means of a teat pipette and the precipitate washed with a little 0·01 per cent. ammonium oxalate solution and again centrifuged. This is repeated three times and the excess ammonium oxalate solution is finally separated from the precipitate by means of a finely-drawn-out piece of glass capillary, which enables the last drops of clear solution to be removed without disturbing the precipitate. The calcium oxalate is dissolved in about 1 ml. of 30 per cent. v/v sulphuric acid which has previously been oxidized with potassium permanganate. The solution is transferred to a convenient titrating tube, heated to 80° C. approximately and titrated with 0·01 N potassium permanganate from a 1 ml. burette (Winteringham, 1945). A blank on the reagents is run concurrently with the determination and the figure is deducted from the final titre.

$$1 \text{ ml. } 0{\cdot}01 \text{ } KMnO_4 \equiv 0{\cdot}02 \text{ mg. Ca.}$$

The success of the method depends on the washing process, where the loss of calcium oxalate by solution is reduced by the presence of ammonium oxalate in the wash liquor but, at the same time, the contamination of the final precipitate with this ammonium oxalate must be minimized ; hence the choice of 0·01 per cent. for the concentration of wash liquid. The solubility of calcium oxalate in water is such that even a single wash with water introduces considerable errors.

Magnesium.

0·1 ml. of the ash solution is pipetted into a 10 ml. stoppered graduated flask. Then in the following order are added :

0·5 ml. 0·2 per cent. calcium chloride solution.

4·0 ml. of reagent which is made up immediately before use in just sufficient quantity for a run of determinations. The reagent is made up in the proportions 1 ml. glycerol, 2 ml. of fresh 1 per cent. starch solution filtered through No. 1 Whatman paper ; 1 ml. of 0·1 per cent. Titan yellow stock solution (Pieters *et al.*, 1948).

1·0 ml. of 2N sodium hydroxide and finally water is added to the mark.

The solution is left for one hour and " spekkered ", using a 1 cm. cell and Ilford No. 604 filters. The instrument drum is set with water to 1·20 and the drum difference figure referred to a calibration graph previously prepared with standards. A fresh calibration graph is prepared whenever a new stock solution of Titan yellow is used. It is necessary to set the drum to 1·20 because of the high blank value caused by the strong colour of the dye.

Iron.

Since a satisfactory method has not been worked out yet, the tentative method at present in use is described below. It is hoped to publish a paper on the subject in due course.

0·25 ml. of ash solution is pipetted into a dry 1 ml. graduated stoppered flask and made up to the mark with reagent, which should not be more than 48 hours old. The reagent is prepared by mixing together 2·8 g. crystalline sodium acetate ; 0·1 g. hydroquinone ; 14 ml. water and 4 ml. of a stock solution of αα-dipyridyl (0·25 per cent. in N.HCl). After standing ten minutes the coloured solution is " spekkered " using a 1 cm. micro cell, neutral and 604 filters. The instrument drum is first set at 1·00 to water. The drum difference figure is referred to a calibration graph previously prepared from standards. A blank is run concurrently.

Manganese.

0·25 ml. of ash solution is pipetted into a 5 ml. beaker which is covered by a watch glass supported on a glass triangle. Chlorides are removed by three successive evaporations to dryness on a water bath with concentrated nitric acid. At the second addition of nitric acid one drop of 30 per cent. hydrogen peroxide is also added. To the final dry residue in the beaker are added 0·1 ml. of copper sulphate solution (50 μg./ml.) as catalyst, 0·1 ml. of 30 per cent. v/v phosphoric acid and the solution heated gently to boiling on a hot plate, 0·5 ml. of 0·5 per cent. sodium periodate solution in 0·5 per cent. v/v nitric acid is then added and the solution boiled gently until pink. After standing on the boiling water bath for one hour the solution is transferred by means of a teat pipette to a 1 ml. graduated flask and made up to the mark with *water freshly distilled from potassium permanganate*. The coloured solution is " spekkered " in a 1 cm. micro cell with Ilford No. 604 and neutral filters. A blank on all reagents is run concurrently and the drum difference figure gives, by reference to a graph previously prepared from standards, the manganese content of the plant material.

Nitrogen.

Reagents.

Catalyst mixture. 75 g. potassium sulphate and 4 g. mercuric sulphate ground together and well mixed.

Potassium hydroxide-thiosulphate solution. 25 ml. of 8 per cent. sodium thiosulphate are added to every 100 ml. of 50 per cent. potassium hydroxide.

Boric acid. 40 g. boric acid and 10 ml. of mixed indicator, diluted to 1 litre.

Mixed Indicator. 0·033 g. bromo cresol green and 0·066 g. methyl red in absolute alcohol.

0·1N *Hydrochloric acid.* 9 ml. concentrated acid diluted to 1 litre, and standardized against sodium carbonate, which has been heated to 280-300° C. in a platinum dish and cooled in a desiccator. The solution should be gently boiled when the mixed indicator shows a grey tint, and the titration completed after cooling.

Hydrochloric acid for titration. 1 ml. ≡ 1 per cent. N on 50 mg. plant material.

$(35{\cdot}72 \times \frac{1}{f})$ ml. of 0·1N hydrochloric acid are diluted to 100 ml., f being the factor of the acid.

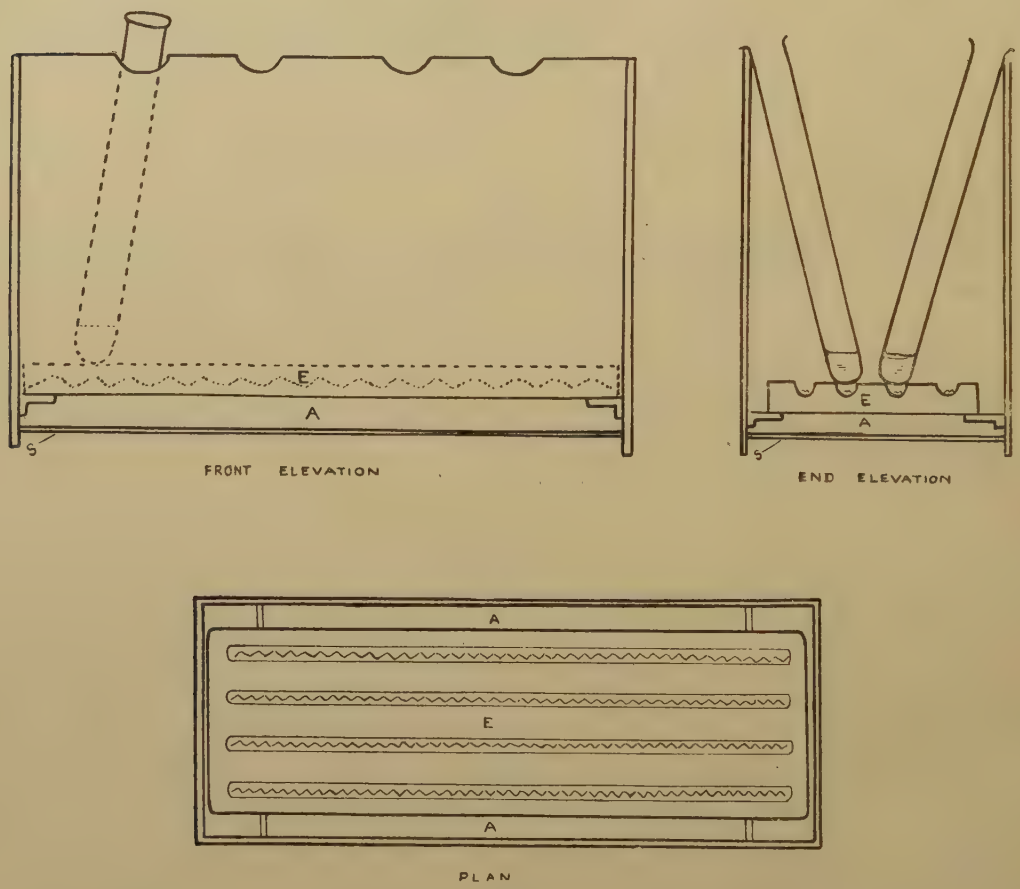

FIG. 2.

Digestion rack made from an electric fire bar and asbestos cement sheeting;
(A) air space. (E) element. (S) asbestos heat shield.

Procedure.

50 mg. of dried plant material is weighed into a dry Pyrex test tube 6 in. × 1 in., and 0·8 g. catalyst mixture and 2 ml. of concentrated sulphuric acid added. A batch of digestions are carried out simultaneously on an electrically-heated rack (Fig. 2). Heating is gentle for five minutes and then vigorous for a further twenty-five minutes. After cooling and diluting with about 4 ml. of water, the contents of the tube are transferred with washings to the distillation apparatus.

The distillation is carried out in a Hoskins apparatus (Gallenkamp b 13645). The steam generator is filled with distilled water to which are added a few mls. of dilute acid and a little granulated zinc to promote steady boiling. The apparatus is thoroughly steamed out before commencing a series of determinations. After transferring the digested solution to the apparatus, a 100 ml. conical flask containing approximately 10 ml. of boric acid is placed with the tip of the condenser below the surface of the acid. Roughly 15 ml. of the " hydroxide-thio " solution is added (leaving a little as seal above the tap), the steam is turned on and the distillation is completed in five minutes. The receiver is lowered fifteen seconds before stopping the distillation and the tip of the condenser washed with water. The conical flask is removed, the steam turned off, and the contents of the inner vessel allowed to siphon into the outer vessel. The funnel, tap and inner vessel are rinsed by running through distilled water immediately. The apparatus is then ready for the next determination.

The contents of the conical flask are titrated to match 10 ml. of boric acid diluted with an equal volume of water. The 0·03572N hydrochloric acid used should be freshly prepared daily from 0·1N acid. A blank determination on all reagents should be run with each set of samples.

The burette reading, minus the blank, represents the nitrogen content of a 50 mg. sample expressed as per cent. nitrogen.

Summary.

Analytical methods are described for the estimation of phosphorus, potassium, calcium, magnesium, iron, manganese and nitrogen. A full analysis can be carried out on a sample of 0·25 g. of dry leaf material.

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THE APPLICATION OF TRACE ELEMENTS TO ALKALINE SOILS

A PRELIMINARY NOTE

By ANNE V. DELAP

The absorption of trace elements by plants is often inadequate on highly calcareous soils, and in places their deficiency becomes a problem of major economic importance. Application of the deficient element to such soils is of little use, since it rapidly becomes unavailable.

It was thought that it might be possible to protect the trace element from the action of the soil by allowing it to be absorbed by peat, which might then act as a reservoir into which roots could penetrate. Pizer (1945) had already obtained an encouraging result with iron by a similar method.

Use was made of a small area of the artificial delta at Bradbourne, described by Garner and Hatcher (1949), where the soil is highly alkaline (pH 8), and on which cereals exhibit extreme manganese deficiency. Peat was soaked in water, 0·1 per cent. and 1 per cent. manganese sulphate solution, respectively. This was applied to the plots to give a layer about one inch deep and dug in. The quantities applied were at the rates of 22 tons of dried peat per acre and of 7·5 cwt. of manganese sulphate per acre when the 1 per cent. solution was used and 0·75 cwt. when the 0·1 per cent. solution was used. Three plots, each of an area of $3\frac{1}{3}$ square yards, were allotted to each treatment, and there were two untreated (control) plots. Wheat, oats and barley were sown on the plots.

A month later, when the plants were about 4 in. high, there were marked differences in growth between the different treatments. Two observers on different occasions considered that the growth of the plants improved in the order—untreated, peat plus water, peat plus 0·1 per cent. manganese sulphate, peat plus 1 per cent. manganese sulphate.

The plants on untreated plots showed severe grey-speck and chlorosis and had a "flattened" appearance. Where peat alone had been applied, growth was distinctly better, but both symptoms were still present. On the plots treated with peat soaked in 0·1 per cent. manganese sulphate, the cereals were better than on the plots just mentioned, though pale green with some chlorotic striping. Where peat treated with 1 per cent. manganese sulphate had been applied, the plants made good growth and their leaves were dark green.

Samples of barley leaves were taken shortly before harvesting and were analysed spectrographically. The percentage manganese content of leaves of plants from all four treatments were identical.

In August, both weeds and cereals were harvested, and Table I shows the marked effect of treatments on the cereals.

TABLE I.

RELATIVE DRY WEIGHTS OF CEREALS AND WEEDS GROWING ON PLOTS RECEIVING DIFFERENT TREATMENTS.

Treatment.	Cereals.	Weeds.
Nil	6	397
Peat and water	12	257
Peat and 0·1 per cent. $MnSO_4$ ..	44	252
Peat and 1 per cent. $MnSO_4$ ..	103	145

Statistical analysis of the results for the peat treatments alone indicated that the effects of the three treatments on the growth of the cereals differ significantly. The figures for the growth of weeds do not differ significantly.

There is little doubt that the treatments, including peat alone, prevented manganese deficiency to an appreciable extent in the cereals, particularly in the barley, and that they tipped the balance between the cereal crops and the weeds in favour of the cereals. The quantities applied were large in relation to the effects produced, but the results provided a starting point for further work.

Summary.

The incorporation in an alkaline soil, on which cereals exhibited severe manganese deficiency, of peat, either soaked in water or in solutions of 0·1 per cent. or 1 per cent. of manganese sulphate respectively, improved the growth of cereals, the effect being greater the heavier the application of manganese sulphate.

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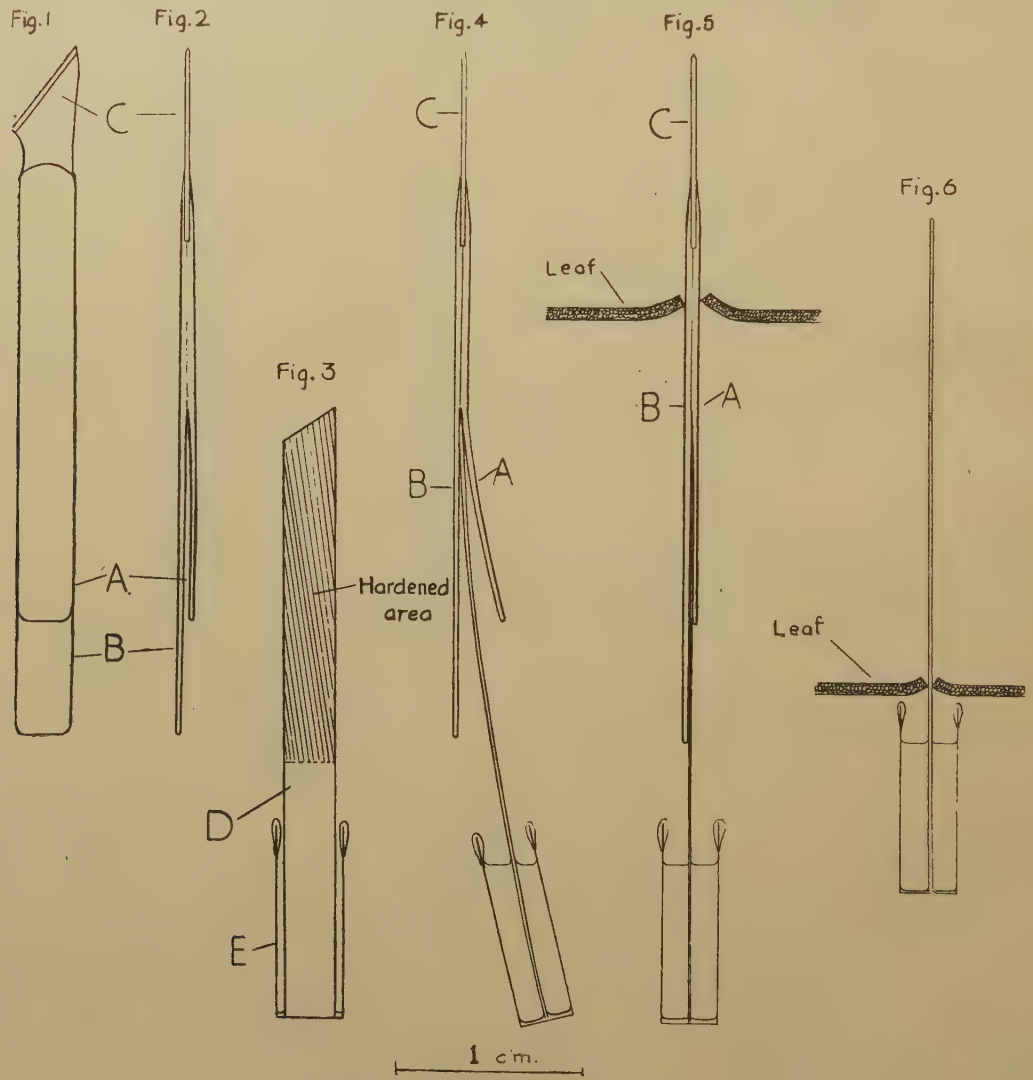
AN INTERVEINAL INJECTION NEEDLE

By ANNE V. DELAP

The published method of interveinal injection involves cutting a slit in the leaf with a scalpel and then threading a hardened filter paper wick through the slit (Roach 1938, Roach and Roberts, 1945). The " needle " described below allows of these operations being performed in one movement and is quick, simple and effective on apple and other similar leaves. With thin, small leaves, such as potato



FIGS. 1-6.

Interveinal injection needle. For details see text

leaflets, it has been found that the passage of the needle results in too much tearing, and the older method is more satisfactory.

A strip of Xylonite, the same width as the filter paper wick, is rubbed down with glass paper until it is about 0·4 mm. thick. Two pieces, A and B, Figs. 1, 2, 4 and 5, 1 in. and 1¼ in. long respectively, are cut off and, with a fragment of razor blade, C, held between them at one end, are stuck together with Durofix for half their length and kept under pressure until dry (Fig. 1). Any roughness is then smoothed off with glass paper.

In use, the filter paper wick (D, Figs. 3-6) of the cellophane tube, E, is slipped between the free ends of the Xylonite strips (Fig. 4) and the needle is pushed, razor blade foremost, through the leaf (Fig. 5) and when drawn up by its tip the injection tube is left supported in position below the leaf by the wick (Fig. 6).

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PATHOLOGY

BACTERIAL INFECTION OF FRUITING SPURS OF SWEET CHERRY (*PSEUDOMONAS MORS-PRUNORUM* WORMALD AND *Ps. PRUNICOLA* WORMALD)

By P. C. R. WEBB*

" Bud infections " of cherry have been recorded by Montgomery and Moore (1945) and spur infections by Grubb (1937), the latter particularly on the late variety Ohio Beauty (syn. Ironsides, August Heart), but no particular emphasis has been laid on their importance in the cycle of the disease.

In the spring of 1946, there were considerable numbers of such spur infections on trees of all ages, and a superficial examination suggested that nearly all the cankers on young cherry trees (over 90 per cent.) arose from spur infections, and that many of the branch cankers on older trees also started in the same way. It was believed that the infection originated in the spur and passed into the branch because longitudinal sections showed that the tissues most affected were the cortical parts of the spurs, which were often disintegrated and sometimes partially dried up, whereas the branch tissues were merely waterlogged and contained many live bacteria like the outer edge of an active canker, which is presumed to be the part most recently infected.

Infected spurs which had not given rise to visible cankers could be distinguished by the fact that some or all of the buds on them were not swelling at the same time as those on healthy spurs. Longitudinal sections showed that the buds failed to develop if there was at any point on the spur an infection which interfered with the vascular system supplying them.

Gum was frequently extruded, and isolations of pathogenic bacteria were readily made from it, from the internal tissues (usually phloem) of infected spurs, and also from the innermost tissues of buds on infected spurs. The outer scales of such buds only gave cultures of the pathogens if the bud was not surface sterilized before dissection.

It was not until November, 1948, that the extremely early stages of spur infection shown in the accompanying photographs were found. The position of the infection suggests that the point of entry is not the freshly formed leaf scar, but the deep crevices in the bark of the spur. These folds occur at intervals along the spur, and frequently contain fungi, including Sclerotinia species, which apparently cause only slight damage. These fungi were not found to be antagonistic to the pathogenic bacteria in culture.

Preliminary attempts to cause spur infection via leaf scars gave inconclusive results, but suggested that entry could only be gained by the bacteria very shortly after the leaf had fallen and that a delay of even an hour in application of a spot of a bacterial suspension to the newly-formed leaf scar made infection uncertain.

In the spring of 1947 an attempt was made to sample the bacterial population on the surface of the tree with a view to obtaining evidence on the source of inoculum for leaf spot. Particular attention was paid to the infected spurs to which reference has been made. Records of correlation of leaf spot with spur infection and branch cankers were impossible, as leaf spot did not appear at the usual time, and remained absent throughout the season.

The sampling method adopted was as follows. A layer of wet sterile cotton wool was placed in close contact with the parts of the tree chosen, covered with cellophane, and left for one hour. The cotton wool was then placed in a glucose-ammonium phosphate medium of pH 7 and incubated at 23° C. for forty-eight hours. A loopful of the culture obtained was placed on the edge of an agar plate and streaked along the sides of a square, the loop being sterilized at each change of direction. This gave the effect of four successive dilutions, and separate colonies could be picked out with ease.

Colonies showing the characteristic radial striations described by Wormald (1937) were selected, and further identified by the behaviour of the organisms on purple lactose agar and gelatine, together with the production of a fluorescent green pigment in alkaline solutions.

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Fig. 1.

Longitudinal sections of fruiting spurs of cherry, variety Ohio Beauty, taken from trees in November, 1948. Leaf scars are indicated by arrows, the dark coloured areas between them being naturally infected with pathogenic bacteria.

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The sites chosen for sampling and the results obtained were as follows :

Site.	*Positive.* (Cultures obtained.)	*Negative.* (No pathogens isolated.)
1. Spurs with retarded buds ..	114	16
2. Healthy spurs	9	121
3. Smooth one-year-old wood ..	11	119
4. Smooth two-year-old wood ..	4	126
5. Crotch of tree	27	103

In addition to the above sites, the surfaces of branch cankers were sampled with extremely variable results, the meaning of which is not clear. During sampling it was found that the normal surface population of pathogenic bacteria on the infected spurs was very small, possibly owing to the fact that the trees had been sprayed some three weeks previously with 6-9-100 Bordeaux mixture. It was not until these spurs had been kept wet for more than half-an-hour that the bacteria emerged in large numbers, giving remarkably pure cultures.

Longitudinal sections of infected spurs were mounted in water, and it was found that the bacteria were violently extruded with translucent granules of a gum-like substance. Extrusion of the latter did not take place without the bacteria, i.e. from spur crevices containing only fungi.

It is considered highly probable that under conditions of prolonged rain, bacteria may emerge from infected spurs on the tree and would provide a possible source of inoculum for leaf-spot.

Summary.

Bacterial infection of the fruiting spurs of sweet cherry is common, and frequently gives rise to stem cankers on nursery material and to branch cankers on both young and older trees. Under conditions of high and prolonged humidity bacteria emerge from such spurs, and in the experiment described viable bacteria were isolated from surfaces which had received 6-9-100 Bordeaux spray three weeks previously.

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EXPERIMENTS ON RUBBERY WOOD DISEASE OF APPLE TREES

A PROGRESS REPORT

By I. W. PRENTICE*

An abnormality known as Rubbery Wood has been recognized for several years in apple trees of the variety Lord Lambourne, and a similar condition has been occasionally noted in Miller's Seedling, James Grieve and Dartmouth Crab (Wallace *et al.*, 1944; Crane, 1945; Beakbane and Thompson, 1945). There are few references in the literature to other abnormalities in the wood of apple trees. Flat Limb, a condition found particularly in Gravenstein, is known in many parts of the world and has been described by Hockey (1943). It is considered by Thomas (1942) to be a virus disease. Branches of Lord Lambourne trees with rubbery wood are often somewhat flattened owing to uneven secondary thickening, but the symptoms are much less extreme than those described for Flat Limb and the diseases are otherwise dissimilar. Thomas and Raphael (1932) have described deficient lignification in apple wood associated with swellings of the shoots and necrosis in the wood.

The most characteristic symptom of the disease is the unusual flexibility of the twigs and smaller branches, which can be detected by bending suitable portions of the tree by hand. Other abnormalities are, however, associated with the disease. The wood is soft and has a rather " cheesy " texture and this is often noticeable during pruning operations. Affected maiden trees frequently develop a vigorous side branch from a point a few inches above ground level and this branch may outstrip the leader. Older trees develop a " weeping " habit as the small branches bend under their own weight or under the weight of crop and become set in this position. Affected trees are generally less vigorous than normal ones.

Microscope sections of affected branches, cut and suitably stained, show that the walls of some of the xylem vessels and tracheids are not lignified in the normal manner but thickened with cellulose only (Beakbane and Thompson, 1945). Such cells occur in patches which appear in the sections as islands of unlignified tissue surrounded by normal cells, and it would appear that the unusual flexibility of the stems is due to this incomplete lignification. Except in the most extreme cases, the fibres of the pericycle are lignified normally.

The disease exists in different degrees of severity and some trees feel very " rubbery " while others are only slightly so. Frequently symptoms are restricted to certain branches of the affected tree. In stained sections, some branches from affected trees appear almost unlignified while others are lignified except for small patches (Figs. 1 and 2). Even in apparently normal trees, groups of a few unlignified cells are occasionally found, and the precise significance of these small groups is unknown.

The experiments to be described, though not conclusive, support the view that the disease is caused by a virus.

When the experiments were started in 1945, the only variety known to be susceptible to the disease was Lord Lambourne and no source of indubitably healthy material was available. Maiden (one-year-old) trees of this variety on Malling type IX rootstocks were obtained from two different sources and planted at East Malling in March, 1945. The trees were classified as rubbery, slightly rubbery, or normal, by bending the stems between the fingers. Four of the ten trees obtained from one source were classified as rubbery or slightly rubbery and the records in subsequent years confirm this assessment. The trees from this source were, therefore, considered unsuitable for experiment and will not be considered further. The results of the hand estimate of the sixteen trees in the sample from the other source are given in Table I. In an attempt to measure flexibility in a more objective manner, the stem of each tree was gripped in a clamp about 10 cm. above ground level and a cord was hooked to the stem 20 cm. above the clamp. The cord passed over a pulley and had a 500 gm. weight attached (see diagram). The deflection of the stem produced by the weight was recorded on a scale.

The diameter of the stem was measured at 10 cm. above the clamp and in all cases fell within the range 0·9 to 1·0 cm. The stems were then cut at 30 in. above soil level (the trees being pruned as dwarf pyramids in subsequent years) and a number of sections were cut from the portions thus removed. These were stained and examined under the microscope and the trees classified as normal

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if the lignification was normal, or rubbery if the lignification was incomplete. The results of this examination are shown in Table I.

TABLE I.

DIAGNOSES OF MAIDEN LORD LAMBOURNE TREES FOR RUBBERY WOOD, *before* ATTEMPTED GRAFT TRANSMISSIONS, 1945.

Tree No.	Hand estimate.	Deflection (cm.) (500 gm. at 20 cm.)	Appearance of stained sections.
1	SR	1·2	N
2	N	1·5	N
3	N	1·0	N
4	R	2·5	R
5	N	0·6	N
6	SR	1·6	N
7	N	0·5	N
8	N	0·6	N
9	SR	1·5	N
10	SR	0·6	N
11	N	0·5	—
12	N	0·6	—
13	R	4·0	—
14	N	0·5	—
15	N	0·6	—
16	N	0·5	—

N = normal. SR = slightly rubbery. R = rubbery. — = not examined.

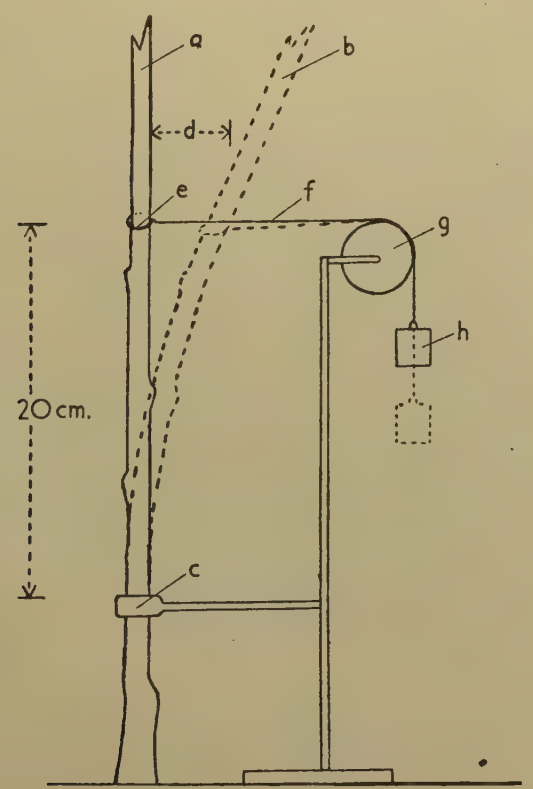

DIAGRAM 1.

a—stem in normal position. b—stem deflected. c—clamp. d—deflection. e—hook. f—cord. g—pulley. h—weight (500 gm.).

As will be seen, each of the tests applied indicated that trees 4 and 13 were rubbery. The status of a number of other trees was doubtful since they were intermediate between normal and rubbery according to one or other of the estimates.

For purposes of comparison, deflection tests were carried out on nineteen trees (Lord Lambourne on type IX rootstocks) selected as rubbery on inspection in the previous season. The diameters of the stems of these trees were from 0·8 to 1·0 cm. and the deflection produced by a 500 gm. weight acting at 20 cm. ranged from 2·7 to 10·0 cm. with an average of 6·2 cm. All of these trees were classified as rubbery by the hand bending test in 1945.

In April, 1945, scions from rubbery Lord Lambourne trees were side-grafted to trees 6 to 10 and trees 14 to 16 and all of the grafts were successful with the exception of that on tree 16. Because the trees were not cut back these scions made little growth. As no Lord Lambourne material known with certainty to be free from rubbery wood was available, the other trees, which acted as controls, remained ungrafted.

In 1946, by hand bending of the branches and main stem, tree 13 was again assessed as rubbery and tree 4 as slightly rubbery. On this occasion tree 3 also was considered to be slightly rubbery and the other trees normal. In 1947 several of the grafted trees were thought to be slightly rubbery, but the symptoms were too slight for positive diagnosis. In January, 1948, estimates were again made by bending a number of branches on each tree. Two sample branches of two-year-old wood were removed from a number of the trees at this time, and sections of these were cut and stained with saffranin and light green, or haematoxylin and orange G. (Figs. 1 and 2). The remaining trees were dug up and, in addition to the branches, the main stem was examined by sectioning and staining. The results of these examinations are shown in Table II, trees 4 and 13, which were rubbery when planted, being omitted.

TABLE II.

DIAGNOSES OF LORD LAMBOURNE TREES FOR RUBBERY WOOD, *after* ATTEMPTED GRAFT TRANSMISSIONS, 1948.

Tree No.	Treatment.	Hand estimate.	Appearance in section.				
			Branch 1	Branch 2	Branch 3	Branch 4	Main stem.
1	Control	N	Ro	Ro			
2	,,	N	R3	Ro			
3	,,	N	Ro	Ro			
5	,,	N	Ro	Ro			
6	Grafted	SR	R3	R4			
7	,,	R	R4	R1			
8	,,	R	R4	R2			
9	,,	SR	R2	R3			
10	,,	VR	R4	R3			
11	Control	N	R3	Ro	R2	R3	R4
12	,,	N	Ro	R1	R1	R1	R1
14	Grafted	N	Ro	R1	Ro	R1	R1
15	,,	SR	R4	R2	R4	R4	R4
*16	,,	SR	R2	R2	R2	—	R1

N = normal. R = rubbery. SR = slightly rubbery. VR = very rubbery. Ro = normal lignification. R1 = very slightly incomplete, R2 = slightly incomplete, R3 = incomplete, R4 = highly incomplete lignification.
* Graft failed.

(Trees 4 and 13, which were assessed as rubbery in 1945, remained rubbery. In section, one branch of tree 4 had highly incomplete lignification and one branch normal lignification; two branches of tree 13 and the main stem each showed highly incomplete lignification.)

It will be seen that, by hand estimate, all of the controls were normal and all of the grafted trees were noticeably rubbery except tree 14, which appeared normal. The results of the histological examination, however, are less definite. It appears that the lignification in one portion of a tree may be highly incomplete while in another portion it is normal (e.g. tree 11). In addition the significance of very slightly incomplete lignification is not clear. It may be that slightly incomplete lignification is normal and represents a form of " tension wood " such as has been described in forest trees. However, incomplete lignification was very evident in some trees which had appeared normal by hand estimate (e.g. trees 2 and 11). If very slightly incomplete lignification is ignored, it will be seen from Table II that, in stained section, two of the six controls and seven of the eight grafted trees were incompletely lignified.

Fig. 2.

Section showing highly deficient lignification. (The light-coloured patches in the wood are unlignified.)

Fig. 1.

Section of branch showing deficient lignification (especially in zone between arrows).

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According to both methods of diagnosis, therefore, it is evident that rubbery wood is more prevalent in the grafted trees than in the controls, and this gives strength to the view that rubbery wood is a graft-transmissible virus disease. The absence of symptoms in tree 14 would then be ascribed to a failure to transmit the virus or to a delay in the development of symptoms in this case. The occurrence of incipient symptoms in some of the controls might be due to natural spread during the course of the experiment. On the other hand, it may be argued that incomplete lignification is a characteristic of the variety and that the tendency towards the expression of this characteristic has been increased by the mere process of grafting. This hypothesis is improbable, but its disproof will require further experiments with adequate controls. For the time being it is suggested that rubbery wood should be treated as a virus disease, and growers should select bud and graft wood only from trees showing no signs of the disease. From the present experiments, it appears that rubbery wood can be diagnosed by hand test with fair accuracy and it should be possible to eliminate a high proportion of affected maiden trees by inspection in the nursery.

Acknowledgements.

The author is indebted to Miss E. C. Thompson for the photographs and for the histological observations included in Table I, and to Miss T. M. Woollcombe for the histological data of Table II.

Summary.

Rubbery wood, a disease of apples, particularly of the variety Lord Lambourne, is described.

Eight Lord Lambourne trees were grafted with scions from affected trees and six trees remained ungrafted. Assessed by hand bending, seven of the grafted trees became rubbery while the ungrafted trees remained normal. Assessed on the basis of an incomplete lignification of the wood in stained sections, seven of the eight grafted trees and two of the six ungrafted trees were rubbery. The results are interpreted as supporting the view that rubbery wood is caused by a virus.

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ENTOMOLOGY

NOTES ON SOME INTERESTING INSECTS OBSERVED IN 1949

By A. M. MASSEE

1. Strawberry Rhynchites (*Rhynchites germanicus* Hb.).

Outbreaks of the Strawberry Rhynchites occur from time to time in various parts of Kent, strawberries in the Otham area being subject to serious attacks in most seasons. This weevil was unusually abundant over an acre of two-year-old Royal Sovereign plants situated at The Heath, East Malling. The grower first noted the twig-cutting injury about the middle of April, and by the end of the month serious harm had been caused to the plants. A dressing of 5 per cent. DDT dust, applied at the rate of 25 lb. per acre, effectively killed the weevils, and no further injury was noted. The secret of success is to apply the dust directly the first signs of damage are noted, and before the weevil starts the twig-cutting operation in earnest.

2. Cherry Borer Beetle (*Platypus cylindrus* F.).

Four species of wood-boring beetles belonging to the family *Scolytidae* infest cultivated fruits, and all of them attack cherry, sometimes causing considerable harm. It is most unusual, however, to find the local and uncommon wood-boring beetle, *Platypus cylindrus* F. causing very similar damage to cherry as the more common species. A number of old cherry trees growing in an orchard at West Malling, Kent, were found to be infested by the beetle, and in some instances the damage was such that it was decided to grub them.

The principal host of this beetle is oak, but beech is sometimes attacked as well. Attacked trees appeared to have been in a sound condition when first infested, but since it is probable that the presence of a certain fungus is necessary to produce the correct conditions to enable the beetle to breed and establish itself, the trees were in fact unhealthy when the beetles first infested them. At first the beetle bores into solid wood, and the initial galleries made by them are difficult to detect. The adults and larvae live together in their burrows in colonies of one hundred or more. Each burrow has a number of branch lines in which the larvae live and feed. The main burrow ends in a rounded cavity in which the ova are deposited. The adults emerge in the summer and egg-laying takes place from August until October.

The beetle possesses the ability to stridulate, and the sound produced may be heard quite readily when one stands close to an infested tree trunk or branch.

It is not possible to state the source of infestation of the attack at West Malling, but this beetle occurs occasionally in oak and beech trees in the neighbourhood.

3. Knotgrass Moth (*Acronycta rumicis* L.).

The caterpillar of this Noctuid Moth feeds upon many kinds of soft fruit, but the strawberry and raspberry seem generally to be preferred. Knotgrass caterpillars were very abundant on a small area of strawberries growing at Great Braxted, Essex, in the autumn of 1948. A number of larvae were collected and reared in the laboratory. Adults started to emerge in April, 1949.

The hairy caterpillar, which is humped on segments four and eleven, is dark brownish grey, ornamented on the back with a series of black patches, which are marked with reddish spots, and a row of white spots on each side ; the spiracles are white marked below with a yellowish wavy line with reddish warts upon it. The insect overwinters as a chrysalis contained in a cocoon. The moth normally appears in June and July, and sometimes in August and September.

This insect frequently causes considerable injury to strawberry plants by devouring the foliage around the crowns of the plants, but if the caterpillars are detected when young they are not difficult to destroy. A DDT dust, applied at the rate of 25 lb. per acre, is sufficient to kill the larvae.

4. Ghost Swift Moth (*Hepialus lupulina* L.).

This species has been referred to previously in these notes, and it is not unusual to find larvae tunnelling into the roots of young hops and destroying them.

An outbreak occurred at Goudhurst, however, which was most exceptional. Many of the hills over an area of seventeen acres of Fuggle hops were affected, and the damage caused was considerable by the end of June. The larvae destroy the very young rootlets completely, and then proceed to tunnel into the older and stouter roots, thus reducing the vigour of the hills. Some of the newly-planted sets were actually killed.

5. The Wood Leopard Moth (*Zeuzera pyrina* L.).

The numerous enquiries made about this insect during the past season suggest that it is much more prevalent in our fruit orchards now than formerly. It is certainly more common than it used to be at East Malling, where many caterpillars have been found tunnelling in the branches of young apple trees at the Research Station and elsewhere. Other enquiries about this pest came from Essex, Norfolk, Suffolk, Sussex and Cambridgeshire.

The caterpillar is a dull whitish yellow, and the spots are black. The head and plates on the first and last segments of the body are black.

The insect may complete its transformations in one year, but more frequently two or even three seasons are spent in the caterpillar stage. The moth emerges in the summer months, and lays her small yellow eggs singly in a crack or wound on a shoot or branch. Owing to the protection afforded to the caterpillar by its mode of tunnelling within the shoot or limb, it is very difficult to destroy by means of insecticides. Frequently the shoot has to be removed and burnt to destroy the caterpillar. Many of the larvae can be killed by poking a piece of wire into the tunnel and hooking them out. Others can be killed by placing a small piece of sodium cyanide in the hole and then plugging up the point of entry with clay.

6. Apple Sawfly (*Hoplocampa testudinea* Klug).

Reports from Kent and Essex indicate that the Apple Sawfly was much more plentiful than usual. Large numbers of adult sawflies were noted in an orchard at East Malling on 22nd April. On this date the apple Worcester Pearmain (a variety very subject to sawfly attack) was in the " pink bud " stage and it was noted that while the sawflies were ovipositing in other white-flowered varieties, including Cox's Orange Pippin and Laxton's Superb, they were paying no attention at all to Worcester Pearmain. This may account for the fact that many Worcester orchards were not seriously troubled by sawfly, although a few Worcester orchards in the neighbourhood were seriously affected.

Another very interesting observation was made at Boreham Essex, on 27th April. Adult sawflies were laying their eggs in the Worcester flowers which were still in the " pink-bud " stage. This is curious in view of the observations made in Kent; it was not an isolated observation, for egg-laying was general in Worcester throughout the orchard, although Cox and Laxton were close at hand.

The fact that that sawfly damage was much more apparent three or four weeks after petal-fall may be accounted for by the larvae migrating from one fruitlet to another, and indeed this habit was so common that all the fruitlets in one cluster became infested in turn by the same larva.

Another interesting characteristic of the sawfly, which has been noted for a number of years, is the fact that it is usually more abundant in the cultivated plantation than in the grass orchard. An explanation for this is not readily forthcoming, but it may well be that the grass provides a less congenial condition for the overwintering stage of the insect than the cultivated soil.

7. Pear Sawfly (*Hoplocampa brevis* Klug).

A very serious outbreak of Pear Sawfly was reported at a fruit farm at Hoo, near Rochester, Kent, on 18th May. The writer visited the fruit farm three days later and found a nine acre pear orchard affected. The infestation was very severe over two acres, and the remainder of the plantation was affected to a lesser degree. Conference was more subject to attack than other varieties, about 50 per cent. of the pear fruitlets being infested. Other kinds infested were Beurré Bosc, Beurré Hardy, Dr. Jules Guyot, Fertility and Souvenir de Congrès.

The severity of the infestation suggests that the insect had persisted in the plantation for a number of years previously, but that it had been overlooked. A survey was made of other pear plantations in the neighbourhood, but no trace of the insect was discovered.

The Pear Sawfly is a well-known pest on the Continent, and it is regarded as being particularly troublesome in Germany, France and Switzerland. There is only one previous record of the occurrence of Pear Sawfly in this country. In 1934 two small outbreaks were reported from private gardens in Cambridge, but the insect was not discovered in commercial pear plantations in the neighbourhood. It had not been recorded again until the present year, in which two further outbreaks were

reported, one at Faversham, Kent, and another at Potter Heigham, near Great Yarmouth, at the end of May, but the reports were not confirmed.

The adult Pear Sawfly is very similar in appearance to the well-known apple species, but it is a little smaller. The eggs are laid during the blossom period in the receptacle of the flower just below the sepals. The oviposition puncture makes a small blister or scar which is plainly visible. On hatching, the larva is creamy white with a black head and black tail markings. After moulting twice the head and tail colour turns brown. Its habits are very similar to those of the larvae of the Apple Sawfly, and the larva migrates from one fruitlet to another very readily. This migration takes place during the day time as well as at night, whereas the apple species normally enters another fruitlet at night. It is common to find all the pear fruitlets of one cluster damaged by the same larva. The larva is fully-fed by the end of May or early June. It falls to the ground and overwinters in the soil at a depth of two to eight inches, as a caterpillar contained in a cocoon. The pupal stage is reached the following March, and the adult emerges in April or early May.

The damage caused by the Pear Sawfly larva is very characteristic (Fig. 1). On hatching from the egg the minute larva bores into the side of the developing fruitlet, or enters by way of the eye. A conspicuous black-ringed hole is made in the side of the fruitlet, and frequently quantities of black frass are exuded which protrude from the entrance of the hole. Ribbon-like scars on the pear fruitlets are made by the larvae, but not so frequently as with the apple species.

The infested plantations at Hoo were thoroughly sprayed with a nicotine and derris insecticide and also with parathion (E605) and derris. These treatments were observed to kill all the migrating larvae, and many within the fruitlets were killed also. It was not considered possible, however, to stamp out the pest completely, because the initial outbreak was not detected soon enough to enable the spray applications to be made at the optimum time.

Pear growers in the Isle of Grain, the Rochester district, East Kent and elsewhere are advised to look out for this formidable new addition to the already numerous pear insects, and any suspected outbreak should be reported forthwith to an officer of the National Agricultural Advisory Service or to the writer. Great vigilance must be exercised next spring to ensure that any further attacks may be noted, and the proper spray applications be made at the appropriate dates.

8. *Kleidocerys resedae* (Panzer).

It is of considerable interest to record the Heteropterous plant bug *Kleidocerys resedae* (Panzer) occurring in apple blossoms at East Malling, and also visiting apple and plum blossoms in plantations in Essex. Although this insect is known to be associated with a number of host plants, it usually occurs on birch and alder. The adult bug may be found all the year round, and the immature forms during the summer months. The feeding habits of the bug are not known, but it is probably an herbivorous species. It cannot be explained why it was attracted to fruit blossoms in Kent and Essex, since it has not been previously noted in commercial orchards.

9. Shy Bug (*Calocoris fulvomaculatus* De Geer).

This common species of capsid bug is known to all hop growers by the name of Shy Bug, so-called because the immature bug runs round to the other side of the foliage or bine directly it is disturbed. It sometimes causes considerable injury to hops by feeding on the leaves and young shoots, frequently causing them to bleed and wilt. It is mainly confined to pole-work gardens, but it occurs to a less extent in wire-work gardens as well.

This insect has persisted each year for over thirty years in a pole-work garden in the Rochester district. It is not regarded as an important pest in this garden at the present time, but might become serious again, if the routine measures carried out to destroy it were omitted.

On 14th June, all stages of the bug were noted in the garden, the adult stage being fairly plentiful. The latter fly very readily in warm sunny weather. The adult females were seen depositing their eggs in the chestnut poles in the garden. A crack in the pole was usually selected for oviposition, but not necessarily so. The winter is passed in the egg state, the minute and extremely active nymphs emerging the following May.

Other host plants of the Shy Bug, besides hop, are black and red currant, nettle and *Rubus* spp., but its preference for hop is well-marked.

10. Cherry Blackfly (*Myzus cerasi* F.).

In the early twenties the Cherry Blackfly was regarded as the most important cherry pest, and it was not uncommon to see all the foliage of cherry trees completely curled and the fruits sticky with honeydew in the month of June. In recent years, however, this pest has caused very little harm in

commercial orchards. The routine application of tar oil winter washes each year has reduced this insect to a minimum.

This season, however, it has been prevalent in all fruitgrowing districts of Kent, and in some orchards considerable damage has been caused, mainly in the Maidstone district. It is curious that this summer it has persisted in cherry orchards which received the routine tar oil winter wash as usual the previous December. The aphids were first noted in the orchards in May and they continued to breed until August, a period of four months. This is most unusual ; the aphides usually produce a winged generation during the latter part of June and then disperse to their summer host plant, a species of *Galium*, and proceed to form new colonies.

The Cherry Blackfly was also noted on Okumiyako (*Prunus serrulata*) by Mr. N. H. Grubb in his garden at Leybourne, Kent.

11. Rosy Leaf-Curling Aphid (*Sappaphis devecta* Wlk.).

Although the Rosy Leaf-Curling Aphid is usually regarded as a Hawthorn species, it is not uncommon on apple in some years. It occurred this year on apple in several orchards in the Rochester district and in a plantation at Boreham, Essex.

The species may readily be recognized by the characteristic leaf-curl it produces on the rosette leaves, and the bright red colour of the foliage. This aphid differs in one respect from the other species found on apples, in that it lays its eggs under the loose bark of the trunk in the latter part of June and in July. Eggs are rarely laid on the main branches and never on the young shoots. This is a very important point economically since it is necessary to remove all the loose bark on the trunk before the tar oil winter wash is applied, otherwise many of the ova will not be wetted by the spray application. This aphid is, in fact, very simple to eradicate provided the loose bark is removed.

12. Oat-Apple Aphid (*Rhopalosiphum insertum* Wlk.).

The fact that the Oat-Apple Aphid has been prevalent again in both winter sprayed and non-sprayed apple orchards throughout Kent, stresses once again how essential it is to embark upon a detailed study of its biology. It may well be that the outbreaks in orchards which received a tar oil winter wash occurred because the spraying was inefficient, but many attacks have been reported in orchards where there is adequate up-to-date equipment and the spraying has been thorough. This suggests that some factor other than the failure of the winter wash application must be sought.

This year the Oat-Apple Aphid remained in the orchards until August, whereas it normally disperses to its summer host at the end of June. Thus it behaved in precisely the same manner as the Cherry Blackfly referred to earlier in this report.

13. Hop-Damson Aphid (*Phorodon humuli* Schr.).

The Hop-Damson Aphid was far more abundant throughout the hop growing districts of Kent than in any other year since 1921. The first winged forms were noted on hops on 14th May, about two weeks earlier than usual, and the aphids persisted in many gardens until the middle of August. The fact that the aphid lived on the hops for four months, and that the winged forms were migrating to hop from sloe and damson over a very long period, largely accounted for the difficulty of eradicating the pest, since as soon as one batch of aphids had been killed, further aphids would fly in and recolonize the hop bines. Thus in many hop gardens several spray applications were necessary to control the pest. Many hop growers used the new phosphorus insecticide parathion, applied at 0·01 per cent., and adequate control of the aphid was obtained, the residual effect of the spray lasting up to two weeks. Thus many of the winged forms which came into the gardens after the parathion had been applied were killed. HETP and TEPP also proved efficacious against the Hop-Damson Aphid, and these preparations were used fairly extensively by growers.

14. Gooseberry Aphid (*Aphis grossulariae* Kltb.).

Although this is the first reference to the Gooseberry Aphid since these notes were started twenty-five years ago, it is recognized that the aphid is widespread in Kent and Sussex, and frequently causes much harm to the bushes. It is often very persistent in gardens and small holdings. It proved to be very abundant in May and June in the Maidstone district, causing considerable leaf-curling and, in severe attacks, malformed fruits. The habits of the Gooseberry Aphid require study in relation to its alternative host plants, which sustain the aphids during the summer months.

15. Woolly Aphid (*Eriosoma lanigerum* Hausm.).

The Apple Woolly Aphid has been increasing steadily in the fruit growing districts of the south-east and eastern counties during the past few years, and the present summer proved ideal for the breeding of the aphid, which reached epidemic proportions in many apple plantations.

The aphids had a very favourable start, and they began breeding during the very warm spell of weather during the middle of April, and strong colonies were established by June. The parasite started to emerge in June, and although it was present in most commercial orchards, it did not breed quickly enough to materially reduce the Woolly Aphid colonies until the late autumn, and by that time considerable damage had been caused.

Cox, Laxton, Lanes, Worcester, Bramley, Newton and Allington were very subject to attack, but many other varieties were infested also.

There is reason to believe that the Woolly Aphid becomes more prevalent in plantations which have been sprayed with a DDT preparation. Many of its natural enemies (mainly predaceous insects) are destroyed by DDT, particularly when it is applied after the blossom period.

It is noteworthy to record the Woolly Aphid parasite, *Aphelinus mali* Hald., in a garden at Finchley, North London, during the summer. The record would suggest that the parasite is spreading rapidly, and that its distribution is extending to the private garden in addition to the commercial orchard.

16. Bryobia Mite (*Bryobia praetiosa* Koch).

Cordon pears planted against the walls of a building at the Research Station were badly infested with the Bryobia Mite. During the second week of April large numbers of mites were noted feeding on the under surfaces of the young leaves, causing them to bleed and exude a sticky substance to which many of the immature mites became entangled, stuck, and eventually died. All these mites were found to be in their first instar (larval forms), having recently emerged from the eggs.

One interesting observation was made regarding a habit of the species. Directly the weather turned cooler, causing a sharp fall in temperature, all the mites would leave the foliage and form compact clusters or colonies on the shoots and spurs, usually seeking the more sheltered positions on the trees nearest the wall.

The Bryobia Mite also occurs on top and soft fruit growing in the open, particularly the gooseberry, and indeed it is often called the Gooseberry Bryobia. It has been noted causing considerable damage to cultivated apples growing in an orchard at Marden, Kent. DDT had been applied at the end of June to control Codling Moth, the result being a severe attack of the Bryobia Mite. This is just one more example of what may happen when DDT is used late in the season.

17. Predaceous mites on fruit trees.

It has been known for many years that several species of predaceous mites occur on cultivated fruit trees, and may be found there at all seasons, but knowledge concerning their food and habits is very meagre.

These mites may be found in some numbers on both sprayed and unsprayed trees, but, as might be expected, they are more plentiful on the latter. Some of the mites may be regarded as general scavengers, while other species have been observed to feed upon the Fruit Tree Red Spider Mite and upon several species of the minute Gall Mites of the family *Phytoptidae*. Two species may be regarded as important predators of Fruit Tree Red Spider Mite, and are quite common in many orchards of Kent and Essex.

Dr. H. H. J. Nesbitt, Ottawa, Canada, a well-known Acarologist, has made a special study of this group of mites during recent years, and the writer is indebted to him for the determination of the species occurring in this country. They are as follows: *Typhlodromus* (*Iphidulus*) *finlandicus* Oud.; *T.* (*I.*) *tiliae* Oud., *Neoseiulus macrophilus* Banks = *Typhlodromus spoofi* Oud. Another species which also occurs commonly on cultivated fruits and hops is known by the name of *Anystis agilis* Banks, and, as its specific name suggests, it is an extremely active red spider-like mite which is also predaceous, but enjoys a varied diet. The habits of all these interesting species are being worked out, since their importance in the economy of the orchard is little understood at present.

18. Greenhouse Red Spider Mite (*Eotetranychus telarius* L.).

Numerous reports from Kent and other fruit growing counties indicate that the Greenhouse Red Spider Mite has been abundant on many kinds of soft fruit, particularly black currant and strawberry. Raspberry has been infested also to a lesser degree. Many of the infestations on black currant have

Fig. 1.

Pear fruitlets attacked by larvae of the Pear Sawfly, *Hoplocampa brevis* (Klug).

[*face p. 130*

FIG. 2.

Slug damage to Raspberry Canes.

been very severe. For example, a four-acre plantation of young black currant bushes was defoliated completely by the end of July ; some of the shoots were malformed and there was no crop. The injury to the bushes was considered to be mainly due to mite attack. Other infestations of equal severity were noted in different parts of Kent, more specially in the Tonbridge district. The hot, dry weather during the summer may be a partial explanation for these severe outbreaks, but it is significant that in practically every case the severe attacks followed the use of DDT, which had been applied to the black currant bushes earlier in the season to control the Black Currant Leaf Midge.

Summary.

An account is given of some of the interesting insects and mites noted in 1949. Special reference is made to the Pear Sawfly, a new pest of cultivated pear in this country. Details are given of the predaceous species of mites found on fruit in England.

APPENDIX

SLUG DAMAGE TO RASPBERRY CANES

BY R. S. PITCHER

Slugs, notably *Agriolimax reticulatus* Müll, commonly feed on the superficial tissues of green raspberry canes in the first few weeks of their growth (May and early June). They rasp away the epidermis and cortical parenchyma in irregular vertical strips (Fig. 2), often leaving traces of slime on the damaged surfaces. This damage has been reproduced experimentally and can be caused by quite young slugs. The epidermis of the canes may split naturally to a varying degree, and it is usual for the slugs to enlarge these splits if they are present, although they are quite capable of abrading the undamaged epidermis.

Although itself of little importance, slug damage has an indirect significance in that it throws the cane open to invasion by other organisms, notably the Raspberry Cane Midge (*Thomasiniana theobaldi*, Barnes) whose larvae also feed on the superficial tissues of these canes. Their damage is usually followed by fungal invasion which may reach the vascular system and kill the canes. Normally the midge lays most of its eggs in the natural splits mentioned above, but in years and on varieties where such splitting is infrequent slug damage offers a suitable alternative to the midge and so may initiate a sequence of injuries which may prove fatal to the cane.

Acknowledgement.

The writer is indebted to Dr. H. F. Barnes of Rothamsted Experimental Station for confirmation of the identity of the slugs.

THE STRAWBERRY APHID, *PENTATRICHOPUS FRAGAEFOLII* (COCK.), AND ITS CONTROL

By G. H. L. DICKER

The Strawberry Aphid, *Pentatrichopus fragaefolii* (Cock.), has assumed great importance in the economy of the British strawberry industry since Massee (1935, 1942) discovered it was the vector of both the Yellow Edge and Crinkle viruses. Although populations do occasionally become so great in May and June that plants are weakened by the direct mechanical effect of feeding, it is primarily due to the great facility with which the viruses are transmitted that this species is rated as such a serious pest. When dealing with a virus vector a much greater degree of control is required than is necessary against aphids causing only mechanical injury, for the danger of virus spread remains as long as any aphids are present on the plants. Furthermore, during the late spring and summer months aphids take only about a fortnight to reach the adult stage and each adult may produce up to three nymphs a day, hence even with very small numbers surviving after the application of sprays the population rapidly builds up again.

Under present conditions it would seem that the most practical method of preventing losses due to virus is the elimination of the vector, but even with modern insecticides such an ideal is impossible to achieve in the field. Failing the attainment of this objective the aim of the present investigation has been to approach it as closely as is economically possible.

Life history.

Unlike most fruit aphids *P. fragaefolii* does not pass the winter in the egg stage but continues breeding viviparously throughout the year, the rate of development varying greatly according to the seasons, being most rapid in late spring and summer and least in winter. In the field population changes follow a definite rhythm. During the first year from the planting of runners the number of aphids rises gradually to a peak in late summer then decreases as winter approaches. On older plants the rhythm is slightly different, the overwintered population remains relatively low until April when an increase, often very rapid, occurs, reaching a peak in late May or June, then follows a rapid decline and within a month the population has dropped to the same level or even lower than before the increase began. With minor fluctuations this low level is maintained until the following April when a similar increase occurs. Aphids are usually most numerous on two-year-old plants, the intensity of infestation tending to decrease with the age of the plant ; of the main commercial varieties Huxley is the most heavily infested, whilst Climax, Lefebvre and Perle de Prague are seldom densely populated. As far as is known the cultivated strawberry is the only plant on which the Strawberry Aphid normally lives under natural conditions.

In addition to wingless aphids which occur throughout the year there are two periods, in May and June and again from October until January, when a small proportion of the total population develops wings. There is ample evidence to show that the winged aphids produced in May and June fly readily when the weather is warm and calm, and these are responsible for the initial infestation of young strawberry beds. Experiments (Greenslade, 1941) have demonstrated that single strawberry plants can be colonized by winged aphids when planted 400 yards from the nearest source of infestation ; in practice there is no doubt the winged aphids often travel much greater distances. Probably there are no areas suitable for runner raising or fruit production in this country, where absolute immunity from infestation by winged forms exists, though the risk decreases with increasing distance from sources of infestation.

It is probable, though there is yet no definite evidence, that some of the autumn winged forms also disperse, especially those maturing in October and November. Other species are on the wing at this time of year, so there seems no reason why the Strawberry Aphid should not also fly ; further, occasional outbreaks of virus have been noted which strongly suggest autumn infection. But, as the total number of winged aphids produced in the autumn is very much smaller than in the late spring and the periods of weather favourable for flight are fewer, the autumn winged forms are far less important both as virus vectors and as sources of aphid infestation than those occurring in the spring.

From the foregoing description of the habits of the Strawberry Aphid it will be seen that, provided runners are freed from aphids at the time of planting and are planted sufficiently far from already

infested beds to avoid any risk of infestation by the wingless forms, then the initial infestation of these plants can only occur through the agency of winged aphids. The important period when this is likely to occur is during May and June, the only time when winged forms of the Strawberry Aphid are known to disperse freely. The main object of the control measures to be described later centres around the elimination of the incoming winged aphids and their progeny before large colonies develop.

Control.

In the past various methods and insecticides have been tested against the Strawberry Aphid, including nicotine and derris sprays, nicotine dust and atomized pyrethrum (Greenslade and Massee, 1939). Of these a nicotine spray was considered most satisfactory, but the low growing habit of the strawberry plant and the presence of many aphids on the undersides of the open leaves made adequate control impossible, due to the difficulty of completely wetting the lower leaf surfaces. The first trials with nicotine vapour (Massee and Greenslade, 1941), carried out in 1939, when an infestation was reduced by 99·8 per cent., heralded a new era in control of this pest.

Further trials, however, showed this method could only be operated successfully when the plants were dry, the air temperature exceeded 60° F. and wind speeds were low. In addition, the available equipment proved much too difficult to manoeuvre on strawberry beds of less than one acre and smaller machines since developed have suffered from a further disadvantage that the narrow sheet allowed only two or three rows to be treated at a time, leading to a high proportion of " outside row " work. The narrow sheet was more difficult to control except during calm periods and the vapour concentration more difficult to maintain. Four years' experiments with nicotine fumigation have given variable results ; under favourable climatic conditions the control usually exceeded 95 per cent., but this method has serious limitations imposed by the weather ; for instance, during the spring of 1948 successful operation of this method was almost impossible.

With the introduction of the organo-phosphorus insecticides the trend has been to revert to spraying in preference to fumigation. During 1949 attention was concentrated on testing two insecticides only, diethyl *p*-nitrophenyl thionphosphate (parathion) and *bis* (*bis*-dimethylamino)-phosphonous anhydride. The former was chosen in preference to HETP or TEPP as it possesses slight residual toxicity and also has the valuable property of penetrating through leaf tissues, a spray deposit on the upper surface being toxic to aphids feeding on the underside ; the latter was chosen as the only systemic at present showing commercial possibilities. Both these compounds are highly toxic to humans and must, therefore be handled with care. Rubber gloves should always be worn when handling the concentrate and operators should avoid contamination from spray drift. Another common danger arises from leaks, either where the lance is attached to the hose or from the trigger valve. Providing the above precautions are strictly observed there should be no risk of injury to operators spraying low-growing crops such as strawberries.

Experiments with parathion.

In laboratory trials, where infested potted plants were dipped, a complete control was obtained with all concentrations including and above 0·0006 per cent. For these experiments technical grade parathion was dissolved in diacetone alcohol and emulsified with the anhydrous *cyclo*hexylamine salt of sulphonated lorol in the proportions 2 : 20 : 1 ; 0·0125 per cent. dioctyl sodium sulphosuccinate being added to each diluted solution to ensure adequate wetting.

Persistence was estimated by dipping clean plants and inoculating the dipped leaves of each plant with twenty-five aphids of all stages. Re-inoculation took place on every second day or at longer intervals if all the previous batch of aphids had not died within this time. Three plants were used for each concentration and all young growth was removed as it appeared to ensure that the aphids remained on treated leaves. At concentrations of 0·00125, 0·005 and 0·02 per cent. respectively, a complete kill was obtained when the plants were inoculated up to the second, fifth and eighth days, whilst some aphids survived when the same plants were inoculated on the fourth, seventh and eleventh days from the time of dipping.

Apart from penetration through the leaf no translocation of the insecticide within the plant has been observed. Aphids continued to feed unharmed from petioles of leaves, the laminae of which had been dipped in parathion, and young leaves could always be readily colonized as soon as they appeared through the crowns of dipped plants.

Field trials.—In the experiments, detailed in Table I, sprays were applied to plots of approximately one-twentieth of an acre except in experiment 4 when a quarter acre was sprayed. A commercial, dispersible liquid containing 20 per cent. parathion was used. Although this preparation contained a spreader the wetting was not uniformly good when the concentration of parathion was

reduced to 0·005 per cent. ; to improve wetting 0·0125 per cent. dioctyl sodium sulphosuccinate was added to certain sprays as indicated by a plus sign in the spreader column. The sprays were applied with double-nozzle lances at 250 lb. pressure using 400-600 gallons per acre, the quantity depending on the size of the plants and the density of the foliage ; for vigorous Huxley plants the higher figure was necessary. Populations were estimated by counting the number of aphids on partially opened sample leaves as described by Greenslade and Pearce (1940), counts being made shortly before spraying and at intervals afterwards. The post-spraying records were the more detailed, one sample leaf being taken from every fifteenth plant in each plot. Experiment 1 was carried out on two-year-old Huxley plants, experiment 2 on a mixed bed of two-year-old Huxley, Lefebvre, Climax and Perle de Prague, experiment 3 on two-year-old Huxley seedlings, and experiment 4 on maidens of Huxley, Lefebvre, Perle de Prague, Jucunda and Early Cambridge.

TABLE I.

FIELD TRIALS WITH PARATHION AGAINST THE STRAWBERRY APHID, 1949.

Parathion per cent.	Spreader.	Date sprayed.	Mean population per sample leaf.		Percentage reduction.
			29th April.	10th May.	
Expt. 1.					
0·0025	+	30th April	194	2·3	98·8
0·005	+	,,		0·3	99·8
0·01	·	,,		0·5	99·7
0·02	·	,,		0·3	99·8
Expt. 2.					
0·0025	·	2nd May	134	32·1	76·0
0·005	·	,,	76	6·3	91·7
0·01	·	,,	123	2·5	98·0
0·02	·	,,	83	0·2	99·8
Expt. 3.			13th May.	23rd May.	
0·00125	+	13th May.	201	5·3	97·4
0·00125	+	,,	206	2·6	98·7
0·0025	+	,,	241	0·6	99·8
0·0025	+	,,	275	0·8	99·7
Expt. 4.			28th June	4th July	
0·005	+	28th June	7·4	0·1	98·6

The results show that all treatments gave a high degree of control except in experiment 2 where the lower concentrations were applied without the addition of a spreader. In experiments 1 and 2, both with and without the addition of a spreader, considerably more aphids survived the 0·0025 per cent. treatment, whilst in experiment 3 the control obtained by 0·0025 per cent. was equal to that obtained with 0·005 per cent. in experiment 1. From these preliminary trials it would appear that whilst a good control of the Strawberry Aphid can be obtained with 0·0025 per cent. parathion, the number of aphids can be still further reduced by doubling the concentration, but above this strength there is very little increase in kill.

Later counts showed that virtually no increase in numbers occurred throughout May on any of the plots treated in experiments 1 and 3, nor with the higher concentrations in experiment 2, whilst on untreated plants populations continued to increase until the first week in June when the normal peak was reached. Thus sprays applied as early as 30th April had effectively eliminated the normal seasonal increase and very greatly reduced the production of winged forms.

On the maidens in experiment 4 the population increased slowly up to late October when counts were discontinued (see Table 3 ; Plot P.10.N). These plants suffered severely from Verticillium Wilt and drought and made little fresh foliage from the end of June until the rains came in October. On more vigorous plants the population would probably have built up more rapidly and a second spray may have been necessary during August.

Experiments with *bis* (*bis*-dimethylamino)-phosphonous anhydride.

A systemic effect due to absorption through the leaves has been demonstrated on maiden, potted plants of the varieties Royal Sovereign and Huxley by dipping all leaves except the youngest and allowing the spray to dry whilst the pot was still inverted ; care was also taken to avoid wetting

the foliage during the routine watering operations. There was thus no risk of the insecticide reaching the soil and being taken in through the root system. A commercial preparation was used, diluted to 0·094 per cent. anhydride, with 0·0125 per cent. dioctyl sodium sulphosuccinate added to ensure good wetting of the leaves. As soon as the spray deposit had dried, the young untreated leaf of each plant was inoculated with twenty-five aphids of all stages. Re-inoculation took place weekly if the previous batch of aphids had all died, or at longer intervals if any survived after this period. The minimum persistence in a batch of three plants, in experiments conducted at monthly intervals, increased from between two and three weeks for plants dipped on 22nd July to over fifteen weeks for treatment on 2nd November ; a reduced systemic effect was observed in plants dipped on 1st December. Further, it was shown that the insecticide is translocated from the leaves to young runners, giving persistence of the same order as noted in the young leaves of the parent plant.

These preliminary results suggest that absorption through the leaves of potted strawberry plants occurs until growth ceases in November. The increase in persistence observed late in the season may be due to a reduction in the rate of increase of leaf area and hence less dilution of the insecticide within the plant, coupled with a less rapid breakdown due to a slowing down of the metabolic processes within the plant. The reduced effect obtained in December is possibly caused by poor absorption into the old leaves or lack of translocation within a practically dormant plant.

Field trials.—With one exception a concentration of 0·094 per cent. anhydride, derived from a commercial preparation, was used in all trials, 0·0125 per cent. dioctyl sodium sulphosuccinate being added to ensure good wetting. 100-150 gallons per acre were applied at 250 lb. pressure as a fine spray from double nozzle lances with the object of wetting the upper surfaces of all leaves. The infestation was assessed by counting the number of aphids on a partly opened leaf taken from plants at regular intervals throughout each plot. The results are presented as percentage infested plants calculated from the number of sample leaves with and without aphids present on them. In general the average population was less than one aphid per sample leaf until the October count. All the experimental strawberries were planted during autumn, 1948, the plants having been dipped in nicotine before planting ; thus, no aphids were present until winged forms arrived during the dispersal period in May and June.

Two large-scale trials were carried out on commercial Special Stock runner beds to investigate the effects of spraying at different dates during the dispersal period. Plots of approximately one acre were each sprayed once between mid-May and the end of June, the latter date coinciding with the end of the dispersal period. Each plot occupied a strip extending the entire width of the field and was arranged according to the order of spraying. One trial, on Royal Sovereign, was abandoned as the infestation was too light ; the results of the other, on Huxley, are presented in Table II.

TABLE II.

THE EFFECT OF SPRAYING HUXLEY AT VARIOUS DATES WITH 0·094 PER CENT. *bis* (*bis*-DIMETHYLAMINO)-PHOSPHONOUS ANHYDRIDE.

Date sprayed.	Percentage infested plants.			
	24th June.	8th July.	3rd August.	19th October.
19th May ..	2·6	1·3	4·1	54·1
1st June ..	2·0	4·0	5·3	78·8
15th June ..	3·3	5·3	15·4	92·6
29th June ..	24·0	8·1	20·7	94·7
Unsprayed ..	23·0	32·7	—	—

It will be seen that sprays applied up to mid-June effected a considerable initial reduction in the number of infested plants, which in the case of those applied on 19th May and 1st June was still very marked on 3rd August. The reduction in infestation following spraying on 29th June was disappointing and may possibly be explained by the fact that by this date the plants had practically ceased growth due to drought and the spray residue was either not readily absorbed or else it was not translocated within the plant. The considerable increase in infestation recorded in October is partly seasonal and partly due to the runners being grown on the isolated block system (Rogers and Buttfield, 1944) whereby runners from corresponding pairs of plants in adjacent rows are trained into a square, with the parent plants at each corner, and intermingle late in the season. The final sample was thus taken from groups of four plants instead of from single ones as previously. To minimize the risk of virus spread the control plot was sprayed in early July. One objection to the layout is a single control and this at an

end of the field ; it is possible the infestation varied across the field though the first sampling of the control and neighbouring plot, which had not then been sprayed, does not indicate any trend.

All the runner beds at the Research Station, also grown on the isolated block system, were sprayed in late June with 0·094 per cent. anhydride (Table III). Since these were primarily designed as pomological experiments no controls could be left, but it is known from unpublished data that infestations of the order observed before spraying normally lead to every plant becoming infested by the end of July. The plots, varying from one-sixteenth to a quarter of an acre, were planted with Royal Sovereign and Paxton (P.2), Climax (P.5) and mixed varieties, mainly Huxley, Lefebvre, Early Cambridge and Perle de Prague (P.10). Each plot was planned as a north (N) and a south (S) unit, these divisions being retained when spraying. Table III shows that the infestation was effectively controlled until September on all plots receiving *bis* (*bis*-dimethylamino)-phosphonous anhydride ; even by 24th October, the normal time for lifting runners, only a light infestation had developed.

TABLE III.

FIELD TRIALS AT EAST MALLING WITH *bis* (*bis*-DIMETHYLAMINO)-PHOSPHONOUS ANHYDRIDE, 1949.

Plot.	Date sprayed.	Percentage infested plants.				
		21st June.	19th July.	24th August.	13th Sept.	24th Oct.
P.2.N	21st June	34·4	0·0	0·0	1·4	10·6
P.2.S	,,	42·3	0·0	1·6	0·0	15·4
P.5.S	,,	50·0	2·2	0·0	0·0	15·6
P.5.N	28th June	52·6	1·3	0·0	3·9	13·5
P.10.S	,,	70·7	5·5	1·6	3·8	11·5
P.10.N*	,,	84·1	14·3	20·4	26·7	48·3
		3rd Oct.	25th Oct.	4th Nov.	5th Jan. 1950.	
N.2.N	17th Oct.	78·1(11·5)	89·2(10·4)	—	—	
N.2.S	,,	84·4(13·1)	71·8(7·0)	—	—	
C.5	,,	83·6(12·3)	86·4(7·3)	78·3(5·7)	62·7(4·1)	

*Sprayed with 0·005 per cent. parathion.

For comparison with *bis* (*bis*-dimethylamino)-phosphonous anhydride the north unit of P.10 was sprayed with 0·005 per cent. parathion. Counts made one and two weeks after spraying showed no difference in infestation on either plot but by 19th July an increase in infestation on plot P.10.N was observed and the percentage infested plants steadily increased. It is suggested this difference is due to the entire aphid population being killed on most of the plants sprayed with *bis* (*bis*-dimethylamino)-phosphonous anhydride, whilst a few aphids survived on certain leaves of many of the plants sprayed with parathion ; as the population increased the aphids spread to the young leaves and were subsequently recorded in sample counts.

In view of the poor control obtained by spraying Huxley on 29th June in the previous experiment (Table II) and the good overall effect when plot P.10.S was sprayed only one day earlier the results on Huxley were compared with those on all the other varieties. These are presented in Table IV and it will be seen that both sprays gave a marked decrease in control on Huxley compared with that obtained on Lefebvre, Early Cambridge and Perle de Prague.

TABLE IV.

EFFECT OF SPRAYING HUXLEY AND OTHER VARIETIES WITH *bis* (*bis*-DIMETHYLAMINO)-PHOSPHONOUS ANHYDRIDE (P.10.S) AND PARATHION (P.10.N).

Plot.	Percentage infested plants.									
	Huxley.					Other varieties.				
	28th June.	19th July.	24th Aug.	13th Sept.	24th Oct.	21st June.	19th July.	24th Aug.	13th Sept.	24th Oct.
P.10.S	100·0	20·1	8·0	12·0	12·0	64·6	1·9	0·0	1·9	11·3
P.10.N	96·4	10·1	29·4	40·9	68·3	75·6	17·6	13·1	15·0	32·5

Further trials (Table III) were conducted on fruiting plants of mixed varieties on 17th October. At this date neither 0·094 nor 0·188 per cent. anhydride applied respectively to plots N.2.N and C.5 and N.2.S caused any appreciable reduction in the number of infested plants or the average number of aphids per sample leaf (given in brackets). The decrease observed on 4th November and 5th January in C.5 can be accounted for by the normal seasonal decline.

From these trials one point emerges very clearly—whilst a marked systemic effect can be obtained on potted strawberries between July and November, and doubtless further experiments will show this to occur during the spring also, the results on field plants are far less consistent. This may be due to two main causes.

1. The leaves of potted plants are dipped and a complete wetting of both sides is obtained, whereas the aim of field spraying has been to get a cover of the upper surfaces only. Hand painting of leaves has shown that about two and a half times as much liquid is needed to wet the under as the upper surface.

2. Since potted plants are watered regularly a more uniform rate of growth is maintained ; the slight shelter afforded by the insectary may also encourage a softer type of growth which in turn may increase absorption.

In general it would appear that *bis* (*bis*-dimethylamino)-phosphonous anhydride will give better control of the Strawberry Aphid on maidens, when applied in May or June, than does parathion, but results may not always be satisfactory. Ripper, Greenslade and Lickerish (1949) have already suggested that this insecticide may not be effective on plants which are mature or have stopped growing and the results obtained on Huxley seem to support this view. There would, however, still appear to be a distinct varietal effect on strawberry, because at the end of June no obvious differences in growth could be detected between any of the varieties sprayed, yet excellent control was obtained except on Huxley. No systemic effect was noted with sprays applied on 17th October, when plants had almost ceased growth.

Insufficient information is at present available from which to calculate the residual effect on plants growing in the field. The results of the first two sprayings, given in Table II, are highly suggestive of such an effect since the dispersal period in 1949 lasted throughout May and June with winged aphids most prevalent at the end of May. Under these conditions the plants would be exposed to risk of infestation for a considerable time after spraying.

Conclusions.

Pending further trials and information on the toxicological aspect it is not yet known how efficient or safe the use of *bis* (*bis*-dimethylamino)-phosphonous anhydride will be on fruiting strawberries when applied pre-blossom in late April.* The results (Table I) have already shown that thorough spraying with 0·005 per cent. parathion will give excellent control at this period. Besides preventing any risk of mechanical injury by aphids this spray has an indirect effect in practically eliminating the production of winged forms and hence reducing the risk of infestation and virus infection to young strawberry beds in the neighbourhood.

For maiden plants, which should be dipped in 0·05 per cent. nicotine as a routine measure before planting, it will be advisable to spray twice during the dispersal period, in the latter half of May and a month afterwards. The preliminary trials described here have indicated that 0·1 per cent. *bis* (*bis*-dimethylamino)-phosphonous anhydride is more effective than parathion, though the former spray should only be applied when the plants are making rapid growth.

It should be emphasized that effective control with parathion is only possible if a complete cover of at least one side of every leaf is obtained and, to achieve this, hand spraying would seem to be necessary, using 400-600 gallons per acre, spraying each plant from two opposite sides. With *bis* (*bis*-dimethylamino)-phosphonous anhydride a good cover is still required but it need not be as complete as when using parathion, only 100-150 gallons per acre giving good results in the 1949 trials. There seems no reason why automatic spraying should not give satisfactory results with this insecticide.

Efforts have been made to find the most suitable type of spray for strawberries. Various combinations of discs and swirl plates have been tested and the most satisfactory cover with least wastage of spray was given by using double-nozzle lances fitted with four hole swirl plates and No. 3 discs.

* Ripper, W. E., Greenslade, R. M., and Hartley, G. S. ("A new systemic insecticide *bis* (*bis*-dimethylamino phosphonous) anhydride". *Bull. ent. Res.*, **40**, 1950, 481-501.) have shown the anhydride to be more effective than parathion when applied in April. These workers recommend that spraying should be carried out not less than four weeks before picking.

Acknowledgements.

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Summary.

The life history of the Strawberry Aphid, *Pentatrichopus fragaefolii* (Cock.), is described with special reference to the dispersal period in May and June. In laboratory trials a complete kill was obtained when infested plants were dipped in solutions containing 0·0006 per cent. diethyl *p*-nitrophenyl thionphosphate (parathion) with 0·0125 per cent. dioctyl sodium sulphosuccinate added as spreader. The residual effect at 0·00125, 0·005 and 0·02 per cent. was shown to break down between 2 and 4, 5 and 7 and 8 and 11 days respectively. From preliminary field trials, using 400-600 gallons per acre, it is concluded no appreciable increase in control is obtained above 0·005 per cent. This concentration applied to fruiting plants at the end of April prevented the normal seasonal rise in population and almost eliminated the production of winged forms.

A systemic effect with *bis* (*bis*-dimethylamino)-phosphonous anhydride has been demonstrated by dipping the leaves of potted strawberries ; both the young leaves produced subsequently and runners being toxic to aphids. A series of field trials in which 0·094 per cent. anhydride was applied at 100-150 gallons per acre to maiden plants of several varieties at the end of June greatly reduced the infestation throughout the summer and was more effective than 0·005 per cent. parathion. In another trial, on maiden Huxley, 0·094 per cent. anhydride gave better control when applied on 19th May or 1st June than on 15th or 29th June. There was evidence of reduced control on the variety Huxley when growth ceased at the end of June due to drought. No insecticidal effect was obtained with 0·094 or 0·188 per cent. on 17th October. Until more information is available on the toxicological aspect it is suggested 0·005 per cent. parathion be used to control the Strawberry Aphid on fruiting plants when applied pre-blossom, whilst 0·1 per cent. *bis* (*bis*-dimethylamino)-phosphonous anhydride may be used on runner beds, two applications, in late May and late June, being recommended.

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THE SHALLOT APHID, *MYZUS ASCALONICUS* DONCASTER, A PEST OF CULTIVATED STRAWBERRIES

By G. H. L. DICKER

Though first described only four years ago (Doncaster, 1946), the Shallot Aphid has been recognized as a distinct species since the winter of 1941, when aphids closely allied to *Myzus persicae* Sulz., but exhibiting slight morphological differences from this well-known pest, were found infesting stored shallots at Spalding. Subsequent observations have shown that this species has a wide range of host plants including lettuce, young onions and cabbage seedlings growing under glass, while among outdoor hosts are listed savoy cabbage and the cultivated strawberry. In addition, Broadbent (1947) found apterae overwintering on clamped swedes. Summarizing the results of trapping winged aphids at various sites between 1942 and 1947, Broadbent and Doncaster (1949) reported the Shallot Aphid as having been taken in all the major geographical areas of England and also in Scotland. Klinkenberg (1946) records it on strawberry in Holland.

The present writer first observed the Shallot Aphid on strawberries at Westerham, Kent, in 1943, when small groups of Royal Sovereign plants, heavily infested with aphids, were exhibiting symptoms superficially resembling those caused by the Severe Crinkle virus. With the exception of the spring of 1947, this species has since been seen annually, both in spring and autumn, on cultivated strawberries in Kent. Only very slight injury was noticed up to 1947 but reports in the spring of 1948 indicated more widespread damage and in 1949 still more serious infestations were both observed and reported. The damage so far noticed has been entirely of a mechanical nature, caused by the feeding of numerous aphids ; there is no evidence that the strawberry viruses are transmitted, though Doncaster and Kassanis (1946) have shown *Myzus ascalonicus* to be an efficient vector of certain other virus diseases.

Recognition of the aphid.

A full description of the apterous and alate viviparous forms is given by Doncaster. A short description is included here which should enable field workers to distinguish the Shallot Aphid from other species known to occur on strawberries.

The apterous viviparous female (Fig. 1) is small, measuring 1-2 mm. in length. The body is coloured light brown or greenish brown with the dorsal surface strongly convex and shining ; frontal tubercules prominent, slightly converging ; antennae as long as body ; cornicles slender in basal half, slightly swollen in distal half, not extending to tip of cauda. The Shallot Aphid is the only species occurring on strawberry which possesses swollen cornicles and this character, together with the converging frontal tubercules, will serve to distinguish it from other species.

Life history.

Under artificial conditions the Shallot Aphid will breed on onions and shallots all the year round but in the field nothing is known of its life cycle between June and October. The sexual forms have never been observed.

Winged aphids migrate to strawberry in October and deposit nymphs which give rise to wingless forms ; viviparous reproduction continues slowly throughout the autumn and winter, increasing in spring. Only wingless aphids are produced until May or early June, when a generation composed entirely of winged aphids occurs ; on maturing these leave the strawberry plants and migrate to an unknown summer host. Broadbent has suggested the summer may be passed on the roots of plants; this may explain why the summer host is not yet known.

Damage.

During the autumn and winter only small numbers of aphids can be found on strawberry plants, living on the undersides of the leaves. As new growth appears in the spring the population increases and the aphids move towards the crown, colonizing young leaves as soon as these appear and later the blossom trusses ; at this time of year comparatively few aphids occur on the mature leaves.

The damage caused is entirely mechanical and its intensity depends on the number of aphids present. In normal seasons no symptoms are visible until late April or early May, when plants, either singly or in small groups, begin to produce abnormal leaves. The petioles are short, the laminae are

small, puckered and twisted along the midribs and curled (Fig. 2). In addition, with the variety Royal Sovereign the leaves are flecked with red or purplish coloured spots. The overall effect is to produce a weakly, stunted plant with very little foliage and distorted blossom trusses which set small fruit of poor quality. As the infestation develops and the damage reduces the leaf area and slows down growth the attacked plants can no longer sustain high populations and many wingless aphids move to neighbouring plants, where similar damage is caused. Thus the area of damaged plants increases and the typical effect observed during May is one of roughly circular patches of stunted plants, the areas increasing week by week until the infestation is checked by spraying or it dies out naturally due to the production of winged forms which migrate from the strawberries. Peak populations are reached about mid-May and all aphids have become winged by about a month later.

In the autumn the distribution of the Shallot Aphid is far from uniform, aphids often being found on only a few scattered plants. Thus in spring the infestation develops as many isolated patches which preserve their identity unless climatic conditions are exceptionally favourable, when they may coalesce and spread over an entire strawberry bed. Injured plants recover rapidly when freed from aphids, but due to the damaged blossom trusses the crop may be greatly reduced.

The absence of the Shallot Aphid in the spring of 1947 was due to the high mortality caused by the very severe weather experienced during February and early March ; a similar effect was noticed with the Strawberry Aphid, *Pentatrichopus fragaefolii* (Cock.) which also continues breeding throughout the winter. In contrast, unusually mild weather occurred from February onwards in both 1948 and 1949, leading to an early build-up of populations which resulted in larger numbers of aphids being present before the winged forms began to appear in May.

From these observations it would appear that following a very severe winter, especially if low temperatures are maintained over a considerable period with the plants exposed, there is extremely little risk of an infestation developing. In a normal season local outbreaks may occur but the areas of damaged plants will be small, whilst in years when the early spring months are exceptionally mild, severe infestations may be anticipated.

Control.

Attacks occur so sporadically that routine measures are unnecessary. Strawberry beds should, however, be watched during early May for the first signs of leaf curling, special vigilance being necessary in years with abnormally mild spring weather. Since the Shallot Aphid causes only mechanical injury adequate control can be obtained by dusting with nicotine providing this is done thoroughly and care is taken to ensure the dust reaches the crown of the plant. If a spray is preferred, 0·005 per cent. parathion will give excellent control. It should be emphasized that by the time leaf curling is visible the infestation has spread to the surrounding plants, and to prevent further injury it will be necessary to spray or dust these in addition to those already exhibiting symptoms. No additional measures will be necessary against the Shallot Aphid if a routine pre-blossom spray is being applied to control the Strawberry Aphid.

Acknowledgements.

The author is greatly indebted to Dr. Hille Ris Lambers for naming the aphids and to Miss E. C. Thompson and E. Yoxall Jones for taking the photographs.

Summary.

The life history of the Shallot Aphid, *Myzus ascalonicus* Doncaster, is described as far as known, with special reference to the cultivated strawberry. Symptoms of attack on strawberry are described and control by dusting with nicotine or spraying with 0·005 per cent. parathion is recommended.

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Fig. 1.

Myzus ascalonicus Doncaster—apterous viviparous female (×45).

Fig. 2.

Royal Sovereign strawberry showing severe stunting and leaf curl due to attack by *Myzus ascalonicus*.

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A NOTE ON THE EFFECT OF DDT IN TAR OIL AGAINST THE APPLE CAPSID, *PLESIOCORIS RUGICOLLIS* FALL.

By G. H. L. DICKER

During a series of field trials primarily directed towards the control of the Apple Blossom Weevil, *Anthonomus pomorum* L. (Dicker, 1950), an opportunity occurred in 1947 to observe the effect of DDT dissolved in tar oil against the Apple Capsid. Due to the complete control obtained on a commercial scale by the addition of 0·1 per cent. DDT to the green cluster lime-sulphur spray it has since been impossible to find a suitably infested orchard where the experiment could be repeated.

The object of this paper is not to suggest that DDT in tar oil is the most satisfactory method of controlling this pest but to demonstrate once more the remarkably persistent effect of a DDT-in-oil spray and to indicate possible disadvantages if the spray residue persists for an unduly long period.

The trial was carried out in an orchard of mixed apples and pears, the apple varieties Lane's Prince Albert and Allington Pippin predominating. Each treatment was replicated three times on plots one-seventh of an acre in size. Technical grade DDT, containing 82 per cent. *p-p'* isomer, was added to a commercially prepared tar oil concentrate of the miscible type a week before spraying and stirred frequently until dissolved. The tar oil was diluted to 5 per cent. of the spray concentrate, and two concentrations of DDT, 0·05 and 0·1 per cent., were used. Due to a prolonged period of frost and snow, spraying was delayed until 12th March, when the control plots and those receiving 0·05 per cent. DDT were sprayed. The trees dried slowly and before the 0·05 per cent. application had been completed a light drizzle set in, later turning to steady rain ; the temperature also dropped and slight freezing of the spray deposit was observed on the branches. The 0·1 per cent. DDT was applied under favourable conditions on 15th March.

Results were assessed by counting scarred apples at harvest time. After picking, the boxes were stacked beneath the trees and a sample of 120 apples was taken from the topmost full box ; where the number of boxes exceeded four the sample was divided equally between every fourth box in the pile. For each treatment six trees of the variety Lane's and three of Allington were sampled from each plot.

TABLE I.

Treatment.	Mean percentage scarred fruits.	
	Allington.	Lane's Prince Albert.
Tar oil + 0·1 per cent. DDT	1·6	5·0
Tar oil + 0·05 per cent. DDT	7·2	10·8
Tar oil only	59·1	57·0

The results, presented in Table I, show that a high degree of control was obtained with 0·1 per cent. DDT and slightly less when the concentration was halved. The figures under-estimate the actual control as nearly all the scarred fruits on the trees receiving 0·1 per cent. DDT and many on those receiving the lower concentration were very lightly marked, indicating the damage had been caused by adult feeding when the apples were already a considerable size ; the absence of heavily-scarred fruits on these trees showed that the adults had not matured on the treated trees but dispersed from the control plots on becoming fully winged.

These results are similar to those obtained by Jary (1949), the main differences being that Jary used DDT as a wettable powder in 7½ per cent. petroleum oil, the latter also being toxic to capsid eggs ; in addition the petroleum spray was applied three weeks later than the tar oil in this experiment.

Hatching of the Apple Capsid normally begins shortly after bud burst and is complete soon after the green cluster stage. In 1947 bud burst occurred about 12th April and the green cluster stage had been reached by 24th April ; therefore 0·1 per cent. DDT in tar oil remained toxic for at least five weeks.

In one trial Jary observed a serious attack of the Fruit Tree Red Spider, *Metatetranychus ulmi* (Koch), on the control plots during July, the infestation becoming general a month later. At East Malling the reverse occurred, the control plots retaining green foliage until the autumn whilst by late

July all trees on the DDT plots, with the exception of one sprayed with 0·05 per cent., were bronzed. This was obviously due to DDT killing off the predatory insects. According to Collyer (1949) the two most important predators are the Black-Kneed Capsid, *Blepharidopterus angulatus* (Fall.), and Anthocorid bugs, both of which were numerous in the orchard. If the abundance of Red Spider was due mainly to DDT killing the Anthocorids these would have succumbed early in the spring when the overwintering adults became active on the trees. If, however, absence of the Black-Kneed Capsid was the cause, then against this insect the DDT must have remained toxic for between three and four months, as eggs do not hatch until the month of June. This striking example once again emphasizes the need for caution when using DDT lest the advantages gained by controlling one pest may be nullified by encouraging the development of another.

Acknowledgement.

The author wishes to thank Miss M. Bennett, who helped both with the spraying and recording of fruit injury.

Summary.

0·05 and 0·1 per cent. DDT dissolved in tar oil applied to two varieties of apple on 12th-15th March, 1947, reduced the percentage scarred fruit from 59·1 and 57·0 to 7·2 and 10·8 and 1·6 and 5·0 respectively. Subsequently a serious attack of the Fruit Tree Red Spider developed on the trees sprayed with DDT.

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OBSERVATIONS ON THE LIFE HISTORY OF THE FRUIT TREE RED SPIDER MITE *METATETRANYCHUS ULMI* (KOCH)

By CATHERINE A. BLAIR

A detailed study of the life history of the Fruit Tree Red Spider Mite on apple trees has been carried out at the Field Laboratory, Porters' Farm, Great Braxted, Essex, during the past three years. Information was required on the date of hatch of the winter eggs of the mite and the number of its summer generations in order that the application of the summer sprays could be timed correctly. The following progress report summarizes certain interesting observations made during the investigation.

The Fruit Tree Red Spider Mite was first recorded by Canestrini and Fanzago (1876) as *Tetranychus pilosus*. The winter egg was recorded in England by Theobald (1909), but he considered it to be of a beneficial species of beetle mite. The mite was first observed in the United States of America by Ewing (1912), who found it in Oregon in 1911.

Much confusion has occurred between the Fruit Tree Red Spider Mite found on deciduous fruit trees and the allied species *Paratetranychus citri* (McG.), found on citrus trees. McGregor and Newcomer (1928) made a comparative study of the anatomy, appearance and biology of the two species and concluded that they were distinct. That found on deciduous fruit trees is now known as *Metatetranychus ulmi* (Koch).

Biology.

Breeding work in the laboratory, together with records taken in the orchard from 1947 to 1949, has established the fact that five generations of the mite occur each season in this country.

The mite overwinters on the tree in the winter egg stage. These eggs are bright red in colour, and have a distinct spine on top. The mean diameter observed was 0·148 mm. Each female lays approximately 15 winter eggs on the lower sides of small branches and twigs, mainly around the buds and between the first and second year wood. If the mite infestation has built up in the autumn winter eggs will be found on the larger branches and trunk, sometimes giving the whole tree a distinctly red appearance.

Hatching of the winter eggs begins about the third week in April, the peak occurring in the third or fourth week of May. Because of this long hatching period two summer sprays are necessary to control the active stages of the mite, one during the first week of June and another three weeks later.

The mite emerges from the winter egg in its larval stage, in which it is pale orange in colour and 0·17 mm. in length, so that it can scarcely be seen on the leaf by the naked eye. This stage can be distinguished from the others which follow by the fact that the larva has only three pairs of legs, while the nymphs and adults have four pairs. The larva moves upwards to the opening leaves and feeds for approximately two days. It then moves to the undersurface of the leaf and passes into a quiescent stage, lasting approximately two days, after which the protonymph emerges leaving the moult skin behind. The protonymph goes through the same phases and gives rise to the deutonymph, which in time emerges either as an adult male or female mite.

The female mite, which is 0·37 mm. long and 0·26 mm. broad, has a decidedly curved back and the tubercules of her dorsal bristles show up as distinct white spots against her general colour, which varies from light red to dark brown with her age. The male is smaller, 0·26 mm. long, slender with long legs, and is orange in colour.

An average of 1·5 summer eggs per day over a period of twenty days are laid by the female mite. These summer eggs are laid on the leaves, usually on the undersurface along the veins and round the edge. They can be distinguished from the winter eggs by their slightly smaller size and paler colour.

The female mite has on the average a larval period of 4·2 days, a nymphal period of 7·8 days and a pre-oviposition period of 3·2 days. The summer eggs have an incubation period of 11·7 days; thus the mite has a life-cycle of approximately twenty-seven days. The development of the mite from egg to adult is of longer duration in the cooler months of spring and autumn than in the higher temperatures of July and August, when the third and fourth generations are passed through very quickly.

A slight variation occurred in the length of the life-cycle in the three seasons during which the mite has been studied, which is associated with differences in the average temperature of these summers. It is interesting to note that in the cool, wet summer of 1948 the results obtained in Essex approximated to those given by Andersen (1947) for Germany, while in the hot, dry summer of 1949 they were very close to those obtained in the United States of America by Newcomer and Yothers (1929).

Owing to the long period of time over which the winter eggs of the mite hatch, overlapping of the generations always occurs, and all stages of the mite, together with summer eggs, may be found on the leaves at the same time.

The first winter eggs can be found in the orchard about the first week of August. They occur on trees which have a high infestation of mites, and are laid by third generation females. Where the infestation is lower, winter eggs are laid somewhat later by mites of the fourth generation. The fifth generation is always a partial one, females of the fourth generation laying both summer and winter eggs. From laboratory experiments there are indications that a single female of the fourth generation can lay both summer and winter eggs.

Parthenogenesis.

It has been established by laboratory experiment that the female of the Fruit Tree Red Spider Mite can reproduce parthenogenetically. An unfertilized female lays eggs from which only males are produced, while the eggs of a fertilized female produce both males and females. It is unlikely that parthenogenesis occurs in the orchard except where the population is extremely low.

Dispersal.

On occasion, when the mite population of an orchard builds up to a high level, dispersal of the mites takes place. The female mite spins a fine silken thread, drops from the leaf when the air is calm, and floats away with the next breeze.

Fluctuation of populations.

Owing to the activity of predaceous insects, the dispersal of female mites, or the effects of the spraying programme, the mite population of an orchard is never static. A block of trees may have a comparatively large population of winter eggs in spring, building up to a high infestation of mites in the third generation. Dispersal then takes place, or the predatory capsid *Blepharidopterus angulatus* (Fall.) drastically reduces the numbers, and in September and October it may be difficult to find a winter egg on the trees.

Damage.

The mite feeds, usually on the undersurface of the leaf, by inserting its fine needle-like stylets through the epidermis and withdrawing the plant juices.

Leaves on which a large and increasing population of mites are feeding go through a distinct series of stages of external damage. At first the leaf shows a faint white speckling, then as the number of feeding punctures increase the areas of damage spread and the whole leaf assumes a dull greyish-green colour. In bad cases the leaf is bronzed, while in the final stage, which only occurs when the leaf has had a very severe attack, it becomes silvery grey.

By sectioning leaves at these various stages it has been found that the mite forces its stylets through the spongy mesophyll and penetrates a cell of the palisade tissue. The damaged cell shrinks in size and the contents appear to coagulate and retreat into the ends of the cell. In very badly damaged leaves there is evidence that the complete contents of the palisade cells are removed.

In sections of badly affected Early Victoria apple leaves the area of shrinkage is so large that an air space is left between the palisade layer and the upper epidermis. This air space explains the silvery appearance of leaves on a tree which has carried a large population of red spider.

Host.

In addition to apple, plum and pear are attacked by the Fruit Tree Red Spider Mite. The former frequently shows very severe damage, but the latter is seldom heavily attacked.

In Essex the mite has been recorded on the following wild hosts : *Prunus spinosa, Crataegus oxycantha, Rosa canina, Pyrus malus, Ulmus* spp., and *Salix* spp. It has also been found on *Ribes sanguineum* and *Cotoneaster* spp. in gardens near orchards.

Summary.

A progress report is given of a study of the life history of the Fruit Tree Red Spider Mite and of the nature of the damage it causes to the foliage of apple trees.

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PLANT PROTECTIVE CHEMISTRY

FIELD EXPERIMENTS ON THE CONTROL OF APPLE SAWFLY, *HOPLOCAMPA TESTUDINEA* (KLUG), BY SOME SYNTHETIC INSECTICIDES

By R. G. DAVIES and J. K. EATON*

The life history of this insect pest under English conditions has been described by Miles (1932) and by Hey and Steer (1934a, 1934b). Female sawflies deposit their eggs within the tissues of the calyx and receptacle while the apples are in blossom. After a period of ten days or so (depending on temperature conditions) the eggs hatch and the newly-emerged larva penetrates the developing fruitlet, on which it usually makes a characteristic ribbon-like scar. Secondary and tertiary penetrations may occur as the larva develops and attacked fruitlets usually fall during " June drop ". The larvae, when fully grown, emerge from the fruits and pupate in the soil, adults emerging during the following spring (or possibly, in a proportion of cases, the year after that) to repeat the cycle. Hey and Steer (*loc. cit.*) were able to show that spraying with 0·05 per cent. nicotine with a wetter at 80 per cent. petal-fall (i.e. before hatching of the eggs normally occurs) could give effective commercial control. This petal-fall spray was considered more reliable than attempts at control by killing the first-stage larva, since the time elapsing between hatching of the larva and its penetration into the fruit is short and the critical timing necessary for the application of such a spray (e.g. derris) renders it impracticable for use by the grower, who cannot easily determine the date at which hatching is taking place in the field.

Subsequent experience of Hey and Steer's recommendations has shown that the 0·05 per cent. nicotine spray at petal-fall sometimes fails to achieve satisfactory control and Kearns (1933) considered that a second treatment with nicotine, some six days later, was necessary when a heavy infestation was present. These occasional failures may partly be due to lack of knowledge of the precise period over which oviposition extends. Massee (1944), for example, found that eggs are sometimes laid after 80 per cent. petal-fall and such eggs would obviously be missed by a single petal-fall application. A more detailed study of oviposition is at present being undertaken by Dr. G. H. L. Dicker, and may result in improved recommendations for timing of the nicotine application or in an explanation of the occasional failure of nicotine. At the same time it was considered worth while to investigate the possibility of replacing nicotine by one of the recently developed synthetic insecticides, some of which are less fugitive in action than nicotine and might, therefore, be expected to confer protection throughout a protracted hatching period. This paper therefore records the conclusions reached from a series of trials carried out between 1946 and 1948 and serves as a preliminary to future work on a larger scale. The main points under investigation were a comparison of seven synthetic compounds and the relative value of applications during the egg stage (i.e. petal-fall) as contrasted with those made at a time when the majority of larvae were hatching.

Materials.

With the exception of the proprietary product containing γ-benzene hexachloride used in the 1947 trials, all the insecticidal formulations used in the present investigation were prepared in the laboratory from technically pure materials or from proprietary materials of known chemical composition. Details of the purity of the materials and of the formulations used are as follows :

1. Nicotine : 95-98 per cent. pure. The wash applied to the trees in seasons 1946-47 was a solution of 0·05 per cent. v/v nicotine and 0·05 per cent. v/v Triton X100 in water. In 1948 the wash contained 0·05 per cent. v/v nicotine, 0·05 per cent. w/v *cyclo*hexylamine dodecyl sulphate (MB320) and 0·5 per cent. v/v acetone.

2. Lethane 384 : A mixture of β-butoxy-β′-thiocyanodiethyl ether and β-thiocyanoethyl laurate in kerosene. The wash used consisted of 0·2 per cent. w/v Lethane 384 with 0·05 per cent. v/v Triton X100.

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3. Lethane HE60 : a solution of β-thiocyanoethyl laurate in kerosene. The wash used consisted of 0·2 per cent. w/v Lethane HE60 with 0·05 per cent. v/v Triton X100.

4. DDT : technical DDT containing 80 per cent. 2 : 2-bis(*p*-chlorophenyl)-1 : 1 : 1-trichloroethane. The wash used contained 0·05 per cent. w/v technical DDT, 0·1 per cent. v/v benzene and 0·05 per cent. v/v Triton X100.

5. HETP : a technical sample, prepared by the reaction of phosphoryl chloride and triethyl phosphate. The wash applied contained 0·05 per cent. v/v technical HETP and 0·05 per cent. v/v Triton X100.

6. γ-Benzene hexachloride : in 1947 a proprietary formulation was used at a strength of 0·01 per cent. w/v *gamma* isomer. In 1948 a laboratory formulation was prepared from technical benzene hexachloride containing 92 per cent. *gamma* isomer. The wash applied to the trees contained 0·01 per cent. w/v *gamma* isomer, 0·05 per cent. w/v MB320 and 0·5 per cent. v/v acetone.

7. Diethyl *p*-nitrophenyl thionphosphate (E.605, parathion) : a technical sample containing 75 per cent. of the active material, the remainder being impurities formed during manufacture. The wash applied contained 0·05 per cent. v/v technical parathion, 0·05 per cent. w/v MB320 and 0·5 per cent. v/v acetone.

8. Chlordane : a technical sample said to contain 90 per cent. by weight of 1 : 2 : 4 : 5 : 6 : 7 : 8 : 8-octachloro-4 : 7-methano-3a : 4 : 7 : 7a-tetrahydroindane. The wash applied consisted of 0·1 per cent. v/v active material, 0·05 per cent. w/v MB320 and 2 per cent. v/v acetone.

It will be noted that all these compounds are contact insecticides, while the organic thiocyano-compounds and parathion are known also to possess ovicidal properties.

All experiments were carried out with between 60 and 90 trees of Worcester Pearmain on Malling IX rootstocks, using a randomized block layout with single-tree plots. Spraying was carried out at a pressure of 200 lb. per sq. in., and percentage infestation by sawfly estimated by collecting and recording damage in all drops together with the picked crop.

1946 Experiment.

Female sawflies were first noted about 22nd April, and by 1st May, when the trees were approaching full bloom, were fairly abundant. Eggs dissected from flowers at this date were all in an early state of development. The trees reached petal-fall by 10th May, and sampling revealed that eggs had been laid in just over 10 per cent. of the flowers. Sawflies were still visiting the flowers when the petal-fall sprays listed in Table I were applied. Sampling of infested flowers at daily intervals was then carried out to determine the date on which maximum hatching might be expected. The cool weather following spraying resulted in a rather prolonged incubation period, but by 22nd May hatching had started and eclosion appeared imminent in many more eggs. The " hatching-spray " was, therefore, applied on 23rd May to those trees in the trial which had not previously been sprayed. At this date 14 per cent. of the eggs had hatched, but no penetrations had occurred. Hatching was complete by 25th May, and numerous penetrations were noted two days afterwards.

TABLE I.

PERCENTAGE FRUITS INFESTED BY APPLE SAWFLY IN 1946.

Treatment.	Per cent. fruits infested.	Infestation (inverse sine transformation).
0·05 per cent. nicotine (petal-fall)	7·6	15·8
0·05 per cent. nicotine (egg-hatch)	6·1	13·5
0·2 per cent. Lethane 384 (petal-fall) ..	16·8	23·9
0·2 per cent. Lethane 384 (egg-hatch) ..	13·6	21·2
0·2 per cent. Lethane HE60 (petal-fall) ..	15·2	22·6
0·2 per cent. Lethane HE60 (egg-hatch) ..	7·3	14·9
0·05 per cent. DDT (petal-fall)	12·4	20·2
0·05 per cent. DDT (egg-hatch)	6·6	14·6
Untreated controls	13·6	21·2
Significant Diff. (P = 0·05)	—	5·8

It will be noted from Table I that the infestation following a petal-fall nicotine spray in 1946 just failed to differ significantly from that in the unsprayed controls. A significant, though not very high, degree of control was obtained with a hatching-spray of Lethane HE60 and of DDT. None of the other sprays gave any appreciable control. One concludes, therefore, that the petal-fall spray of

nicotine cannot be replaced satisfactorily by one of DDT or the Lethanes and that, though hatching-sprays of Lethane HE60 and DDT gave some control, this was not significantly greater than that obtained with nicotine at petal-fall and the great inconvenience of such sprays (which require careful timing) makes them of little value. The ineffectiveness of DDT at petal-fall and its partial effectiveness at egg-hatch serves in some measure to explain the rather inconsistent results which had been obtained in an earlier trial (not reported here) with this compound.

1947 Experiment.

Once again an attempt was made to distinguish between the activity of sprays applied at petal-fall and those at egg-hatch, the previous season's work with DDT and Lethane HE60 having demonstrated that differences could occur and might be of value in interpreting the results of other workers. None of the previous sprays having shown great promise, two other synthetics were used in 1947, namely, hexaethyl tetraphosphate and γ-benzene hexachloride. The petal-fall spray was applied on 16th May, when some 10 per cent. of the blossoms showed oviposition scars. The weather after petal-fall was warmer than in 1946 and the incubation period of the egg correspondingly shorter. About 5 per cent. of the eggs had hatched by 21st May, and 20 per cent. by 23rd May. The hatching spray was, therefore, applied on 24th May, and further sampling showed that hatching was complete by 27th May, when some penetrations were also noted.

TABLE II.

PERCENTAGE FRUITS INFESTED BY APPLE SAWFLY IN 1947.

Treatment.	Per cent. fruits infested.	Infestation (inverse sine transformation).
0·05 per cent. hexaethyl tetraphosphate (petal-fall)	13·6	20·8
0·05 per cent. hexaethyl tetraphosphate (egg-hatch)	14·3	21·6
0·01 per cent. γ-benzene hexachloride (petal-fall)	0·5	3·0
0·01 per cent. γ-benzene hexachloride (egg-hatch)	0·7	4·0
0·05 per cent. nicotine (petal-fall)	0·6	3·3
Unsprayed controls	14·7	22·4
Significant Diff. (P = 0·05)	—	4·2

The results shown in Table II indicate the complete ineffectiveness of hexaethyl tetraphosphate, applied either as a petal-fall spray or when the majority of larvae are hatching out. On the other hand, γ-benzene hexachloride gave excellent control at both application dates. It is not, however, clear from trials of this type whether the benzene hexachloride exerts a directly ovicidal effect or whether the control obtained depends on the retention within the receptacle of the flower of a deposit of benzene hexachloride which is toxic to the newly-hatched larva. Neither is it known whether, if a direct ovicidal effect occurs, this is due to the fumigant effect of benzene hexachloride which has a rather high vapour pressure. The fact that the eggs are laid within the receptacular tissues suggests that some sort of action at a distance might occur, but it has been observed that as the egg swells during embryonic development by the absorption of water it frequently causes the rupture of the thin layers of plant tissue separating it from the cavity of the receptacle and this might permit contact of the spray-liquid with the egg.

1948 Experiment.

Trees were in full bloom by 26th April, but only a small proportion of flowers bore oviposition scars at this date. By 5th May petal-fall was well advanced and the first spraying took place on 8th May, the insecticides used being given in Table III. Hatching was first noted on 12th May and by 14th May about 20 per cent. of the eggs had hatched, though no penetrations had occurred. The hatching sprays were applied on 15th May. By 19th May, numerous penetrations had taken place, though some eggs were still unhatched and a few newly-hatched larvae were still in the receptacular tissues prior to penetrating the sides of the fruitlets.

Table III shows the results obtained and, in addition to confirming the results of 1947 with γ-benzene hexachloride, indicates the high degree of control following applications of diethyl *p*-nitrophenyl thionphosphate and chlordane at either spraying date. In all cases, the control obtained with the synthetic compounds was significantly greater than that resulting from the petal-fall spray of nicotine.

TABLE III.

PERCENTAGE FRUITS INFESTED BY APPLE SAWFLY IN 1948.

Treatment.	Per cent. fruits infested.	Infestation (inverse sine transformation).
0·05 per cent. diethyl *p*-nitrophenyl thionphosphate (petal-fall)	0·2	0·8
0·05 per cent. diethyl *p*-nitro-phenyl thionphosphate (egg-hatch)	0·4	1·6
0·01 per cent. γ-benzene hexachloride (petal-fall)	0·1	0·9
0·01 per cent. γ-benzene hexachloride (egg-hatch)	0·3	1·7
0·1 per cent. chlordane (petal-fall	0·0	0·0
0·1 per cent. chlordane (egg-hatch)	1·3	5·7
0·05 per cent. nicotine (petal-fall)	4·0	10·9
Unsprayed controls	32·3	34·6
Significant Diff. (P = 0·05)	—	4·2

Discussion.

The results given above indicate that three of the newer synthetic insecticides, namely, γ-benzene hexachloride, diethyl *p*-nitrophenyl thionphosphate and chlordane, are effective in controlling Apple Sawfly, but it still remains to be determined how they achieve this. If they do so by the formation of a persistent deposit within the calyx cup or on the surface of the fruit, it seems strange that DDT, which is known, under most conditions, to have a greater residual effect, should be relatively less effective. Apparently the insect exhibits a specific lack of susceptibility to DDT and this is certainly also true of hexaethyl tetraphosphate, which is without effect on either the egg or the first-stage larva. Perhaps of even greater importance for future work, however, is the extent to which the concentration of toxicant in the spray can be reduced while still maintaining control and, bound up with this, information is urgently needed on the effect which different concentrations of these toxicants might have on the beneficial fauna of the orchard. Thus it is known for DDT and, less fully, for benzene hexachloride that they have a marked effect on the predaceous fauna which results in outbreaks of the Fruit Tree Red Spider Mite, *Metatetranychus ulmi* (Koch), when they are applied after the green-cluster stage of fruit-bud development. As diethyl *p*-nitrophenyl thionphosphate is known to be somewhat toxic to all stages of *M. ulmi* (especially the summer stages) it is perhaps unlikely that its use for sawfly control would result in severe outbreaks of the mite, but the effect on pollinating insects when used year after year in the same orchard might well be serious. Nothing seems to be known as yet of the effect of chlordane on beneficial insects. Until these aspects of the problem have been explored it would be premature to recommend any of the synthetics as a substitute for nicotine in Apple Sawfly control.

Acknowledgements.

We are indebted to Dr. H. Shaw for his advice in the early stages of this work and to Miss M. Bennett and Mr. R. G. Gambrill for their assistance in the field work.

Summary.

γ-Benzene hexachloride, diethyl *p*-nitrophenyl thionphosphate (E605, parathion) and the chlorinated hydrocarbon, chlordane, were all shown to give control of Apple Sawfly equal to or better than that afforded by a petal-fall spray of nicotine.

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Section IV

BULLETINS FOR FRUITGROWERS

OBSERVATIONS ON THE PRUNING OF BUSH APPLES BY RENEWAL AND SPUR METHODS*

By A. P. PRESTON

At the outset it should be made clear that this article does not attempt to inform its readers as to how pruning should be carried out, for adequate information already exists in various books and journals. It is the writer's intention rather to examine the two main methods of pruning bush apple trees at present widely used, in the light of the available evidence from a comparative field trial of these methods on mature trees of Cox's Orange Pippin which has been in progress now for the last five years at East Malling Research Station.

Many people are now planting their fruit gardens with cordon or dwarf pyramid trees, planned so as to yield a moderate quantity of different varieties of apple over as long a period as possible. Other gardeners prefer, or find their new garden already planted with, larger bush apple trees worked perhaps on a vigorous rootstock such as M.II. The spur pruning method has been applied successfully to both intensively planted trees and the larger bush trees, and Mr. C. R. Thompson, in his recent book on the renewal methods, claims that intensively planted apple trees respond satisfactorily to these methods also.

Briefly, spur pruning aims at producing the fruit close to the main framework branches on short natural spurs with varieties which spur readily, as well as on artificial spurs built up by the fairly hard cutting back of laterals each year. In time many of these spurs become long and crowded and judicious spur shortening and perhaps spur thinning will be necessary. Provision also has to be made for new branches to replace any broken framework branches or to fill a space within the tree, by taking a suitably placed lateral and treating it as a replacement branch, leader tipping it each year until it has attained sufficient height and adequate rigidity to carry a fair quantity of fruit.

The renewal method aims at obtaining a successional supply of young shoots, blossom buds and new branches. Some one-year-old laterals may be cut back to one or two inches to produce more laterals next year, while others are left in the tree unpruned to form blossom buds. In the following year a proportion of these uncut laterals, now two years old, may be shortened back to nine or twelve inches, to a good fruit bud, while others are left unpruned to form three-year-old uncut cropping laterals, and in the following winter these are stubbed back to two or three inches to produce in the following year more one-year-old laterals, and so a successional supply of young bearing wood is maintained in the tree. Main branch leaders are tipped annually until they have covered their allotted space, leader tipping then ceases and continuous cropping on long laterals soon brings the branches slowly downwards. In the meantime the pruner has to select one or more suitably placed laterals along each framework branch and leader tip these as replacement branches for the future. By tipping these leaders back to selected buds they may be directed where desired and will eventually replace older branches that may have broken or been brought too near the ground by heavy cropping and need cutting away.

Therefore, with spur-pruned trees we have the majority of blossom buds carried on established spurs, whereas with the renewal-pruned tree they occur on relatively young wood of different ages. This fact is of importance when considering the blossom period of Cox's Orange Pippin trees under the two pruning methods.

The Effect of Pruning Method on Blossoming.

In the second year of the comparative trial blossom records were taken. Although there was no appreciable difference between the opening of the first flowers on renewal- and spur-pruned trees, fourteen days later, when all the blossoms on established spurs were over, the renewal-pruned trees

* Reproduced by permission of the Royal Horticultural Society from *The Fruit Year Book* for 1949.

had twenty blossom trusses open on a sample branch of each tree, whereas the spur-pruned tree had less than three blossom trusses open at that time.

The following year more intensive records were made, blossom trusses having three or more flowers open were counted each day during the blossom period on established spurs, and on the young fruiting wood one, two and three years old. Large whole branches, one on the north side and one on the south side of each tree, were used for these observations. The records showed that blossoms on established spurs opened first and rapidly reached their peak for the maximum number open on any one day, so that in this particular year they had passed their peak and were falling rapidly by the fifth day. These blossoms were closely followed by blossoms on three-year-old wood, which were followed later by blossoms on two-year-old wood. Finally the axillary blossoms on the one-year-old wood opened. The blossom season that year was unusually short, yet in spite of this the blossoms on two- and one-year-old wood were considerably later in opening than the blossoms on established spurs. This blossoming sequence on fruiting wood of different ages has now been recorded and checked over the past four seasons under varying spring weather conditions and some useful deductions can now be made.

From these observations it seems clear that the renewal-pruned tree is in a more favourable position during the blossom period, as far as obtaining effective pollination is concerned, than the spur-pruned tree. The spur-pruned tree may have, on a mature tree of Cox's Orange Pippin, over 90 per cent. of its blossoms on old established spurs, the remainder of the blossoms occurring on the young wood at the extreme ends of the branches. In a good blossoming year, with good weather conditions for the pollinating insects during the first week of flowering, a heavy crop may be expected to set on the established spurs, but if weather conditions are unfavourable for pollination during the first week a poor set of fruit is likely to result. The renewal-pruned tree, carrying its blossoms on established spurs as well as on young wood one, two and three years old, has more blossoms open during the latter part of the blossom period than the spur-pruned tree ; consequently, should the weather conditions be unfavourable for pollination during the first week of flowering there is ample opportunity for the tree to set a good crop with the later blossoms on the young wood. It is apparent, therefore, that although spur-pruned trees may carry heavy crops in some years where there is opportunity to set fruit on the numerous but relatively short-lived spurs, the renewal-pruned tree provides a valuable safeguard against poor setting conditions during any particular portion of the blossom period by spreading its blossoms over the whole period more evenly.

It is worth mentioning that further observations have shown that blossoms on the same aged wood on spur- and renewal-pruned trees do not differ in their time of flowering, thus blossoms on three-year-old wood on spur-pruned trees open at the same time and last as long as blossoms on three-year-old wood on renewal-pruned trees. It is the different proportions in which these blossoms occur on the different aged wood which give the advantage in many seasons to the renewal-pruned trees.

The Effect of Pruning Method on Quantity and Quality of Fruit.

The crop records from the field trial provide interesting indications of the interactions between pruning method, weather conditions at time of blossoming and subsequent crop.

During the first year little difference in crop could be expected between the two methods, as the renewal-pruned trees had only established spurs and some one-year-old unpruned laterals available for blossoming. A small difference of 5 per cent. in amount of crop in favour of the renewal-pruned trees was recorded. In the second year, however, the renewal-pruned trees carried 66 per cent. more fruit than the spur-pruned trees, an average of 52 lb. more per tree. It seemed likely that this increase was due to the better setting of the fruitlets on the renewal-pruned trees, which had a more effective blossom period, for although both sets of trees blossomed profusely, spring frosts that year caused some damage to the early blossoms.

The following year, 1947, was a very favourable year for Cox's Orange Pippin at East Malling ; good conditions for pollinating insects were recorded almost throughout the entire blossom period, and spring frosts were absent. Both sets of trees blossomed and set heavily and although the renewal-pruned trees carried a mean crop of 336 lb. per tree, while the spur-pruned trees carried 267 lb. per tree, these figures when subjected to analysis showed that this increase might be due to chance. That record certainly seems to bear out the hypothesis mentioned already concerning the effects of pruning on blossoming, namely, that given good conditions during blossoming there should be ample opportunity for the spur-pruned trees to set a very full crop on the relatively short-lived, but more numerous, blossoms on established spurs.

Throughout the trial the fruit from renewal-pruned trees has been consistently better coloured than the fruit from the spur-pruned trees. This applies to the amount of red colour and may well be due to the better exposure of the fruit to sunlight, since much of it hangs from the long unpruned

Fig. 1.

Main branch from a renewal-pruned tree of Cox's Orange Pippin ; leader-tipping has ceased and the branch has been pulled down with successive crops. Replacement leaders A and B are being tipped each year to replace eventually the present branch. This branch shows one- and two-year-old fruiting laterals. A three-year-old cropping lateral was stubbed back to three inches at C last winter, from which a new shoot is now growing.

[*face p. 152*

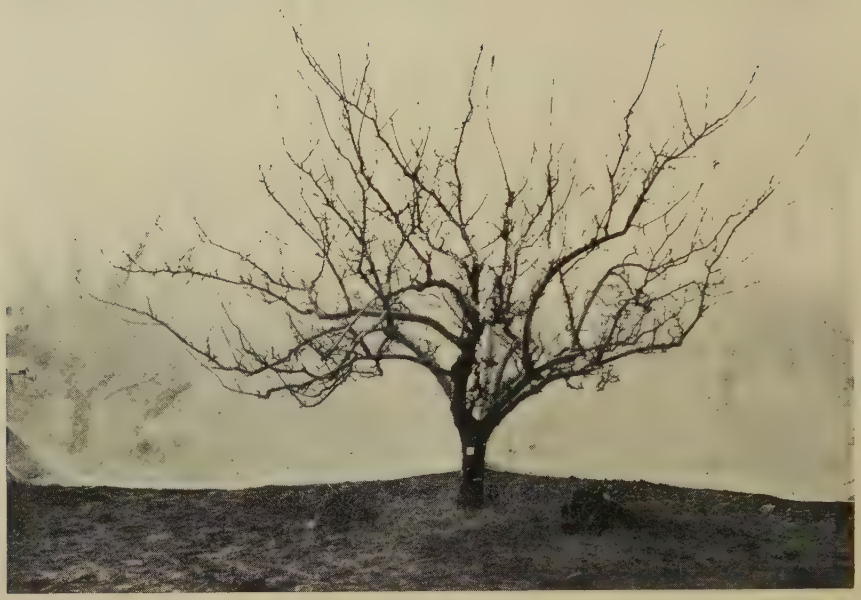


FIG. 2.

Cox's Orange Pippin tree after winter pruning by the renewal method for the third season. Note the small proportion of young wood prunings removed on the left; older prunings are on the right.

FIG. 3.

Cox's Orange Pippin tree after winter pruning by the established-spur method. Note the large amount of one-year-old wood prunings removed from the tree on the left; older prunings are on the right.

laterals spaced along the main branches. The size of fruit, too, has shown a difference between the pruning methods. Renewal-pruned trees have carried rather smaller-sized fruit than the spur-pruned trees. With Cox's Orange Pippin this is an advantage, for medium-sized fruit, giving perhaps four or five to a pound, are much preferred to larger fruit for dessert purposes. So that the greater weight of crop from renewal-pruned trees was due to a larger number of fruit, which seems to imply better setting at blossom-time.

Further years' work will no doubt confirm the observations already made, while much remains to be learnt from the behaviour of blossoms and fruitlets at different stages of development under varying spring weather conditions.

Discussion.

The two pruning treatments were first applied in this field trial to vigorous trees of Cox's Orange Pippin when they were thirty years of age. The trees had previously been spur pruned for a number of years, so that many compound spurs had to be reduced in size and number while the trees which were to be renewal pruned needed considerable branch spacing. There are two important practical points here: firstly, as the crop records have shown, the renewal method is capable of bringing strong growing trees into heavy cropping, and secondly, when converting mature trees to the method for the first time it is essential to allow sufficient room for the full development of the cropping laterals ; this may mean a considerable reduction in the number of main framework branches during the first year or two.

With the converted trees in this trial, even the renewal-pruned trees were carrying a large proportion of their blossoms on established spurs, so that it would be interesting to know how the trees would react in regard to relative times of blossoming if the established spurs were absent, so that the tree could blossom only on one-, two- and three-year-old laterals. Would the blossoming of the three-year-old laterals be brought forward so that they blossomed at the same time as the established spurs ? This point is now being tested at East Malling, together with comprehensive trials, including many varieties of apple on different rootstocks, of established-spur and renewal pruning on young open-centre and delayed-open-centre trees. The life histories of these trees are being closely recorded so that early or delayed blossoming and cropping due to any particular pruning treatment may be seen.

Finally, the renewal method of pruning requires skill and judgement in its application and it needs adapting to the previous season's growth of each tree each year, but there seems little doubt that with over-vigorous trees of Cox's Orange Pippin it is a method capable of bringing the trees into a better condition for cropping.

Summary.

A popular account of an experiment concerning two methods of pruning bush apple trees that are widely used nowadays.

TOWARDS THE CONTROL OF BIENNIAL BEARING

By MOYA H. E. DAVIES

Biennial bearing is recognized as a serious problem by fruit-growers throughout the world and has been the subject of detailed study at East Malling since 1946. The work at Malling is confined to apples, although biennial bearing occurs in many kinds of fruit, including mangoes, olives and citrus as well as pears and plums.

The biennial habit seems to be independent of differences in weather conditions from year to year, and in the same orchard it is possible to have some trees carrying a heavy crop alongside others carrying no crop. The tendency to bear a crop in alternate years is characteristic of certain varieties, such as Miller's Seedling, Laxton's Superb, Newton Wonder and Bramley's Seedling, whereas other varieties, e.g. Worcester Pearmain, normally bear every year. Some varieties fall between these extremes and only have occasional " off " years ; Cox's Orange Pippin behaves in this way.

Young trees do not usually show this cropping rhythm until they are allowed to overcrop one year. The following year then becomes an " off " year with a biennial variety. Pruning and manuring can play a large part in starting such a cropping rhythm but spring frost damage to blossom is possibly the most important single factor, especially as it can cause trees of all ages, over a wide area of the country, to fall into step, through the destruction of the crop one year followed by the development of excessive fruit bud for the succeeding year.

The prevention of overcropping is the first step in controlling biennial bearing. In the " on " year this can be done by removing a proportion of the fruit buds, or the blossoms, or the fruitlets. In the apple, the development of fruit buds for any year begins in June of the previous year, in competition with the swelling fruits. In order to ensure that sufficient fruit bud is formed for the next year, thinning must be done before this time. In practice, fruit thinning must be completed within thirty days of full bloom. In orchards where fruit thinning is started at the same end each year, it has been found that cropping is regular at that end and biennial at the other. Where thinning is carried out as a routine operation, therefore, it is advisable to work from a different end of the orchard each year. In biennial varieties it is important to aim at maintaining a high proportion of leaves to fruits rather than to thin to leave a certain distance between fruits. The best proportion for each variety will have to be determined by trial, but at least twenty leaves to each fruit seems to be essential.

Because of the difficulty of completing fruit thinning within the necessary period, recent trials have been conducted at East Malling on the earlier treatments, the thinning of fruit buds (" bud-rubbing ") and blossoms. Both were done by hand and as yet have served only as experimental methods of control. Bud-rubbing was done at the end of the dormant season (the end of March to beginning of April) when fruit and wood buds could readily be distinguished. On the variety Miller's Seedling, 86 per cent. of the fruit buds were removed by pushing off all the buds from each of two successive complex spurs and all but one from the third, starting at the base of each branch and working upwards.

Similarly, 85 per cent. of the blossom trusses were removed from the same variety in mid-April at the pink bud stage. All the blossom trusses were removed from two out of every three complex spurs, and all but one from the third. In 1946 the treatments were applied to branches, and in 1947 to whole trees. In the years since treatment the trees have borne regularly ; there was, however, a reduction in crop in the year of treatment in both cases. Where the treatments have been applied to whole trees, the total crop harvested in the first two years was greater than for untreated trees, despite the much heavier cropping of the latter in alternate years. In addition the size and general quality of the fruit on treated trees was far better.

There is little to choose between bud-rubbing and blossom-thinning as regards effectiveness. As yet both operations must be done by hand, and therefore cannot be carried out on a large scale. Both are slow and laborious, but more time is available for bud-rubbing than for thinning which must be fitted into the short blossom period. The number of years of regular cropping that may be expected after one bud-rubbing or blossom-thinning treatment is being studied. Where it is possible to maintain a balance between growth and cropping for many years by a single treatment it may seem worth while even if much time and labour are involved, but it is probable that the effect wears off after only a few years, and in any event the balance would be upset by a severe spring frost.

The possibility of using chemical sprays and mechanical means to reduce the labour of blossom-thinning is also being investigated. The use of these introduces the undesirable complications of spur and foliage injury, and it is not yet possible to make any recommendations.

Pruning plays an important part in maintaining a balance between growth and fruiting. Before the " off " year, pruning should aim at reducing the amount of wood available for bearing fruit buds in the following " on " year, by shortening spurs, maiden laterals and leaders. Before the " on " year, spur reduction is recommended, to cut out excess fruit buds, but the maiden laterals should be left unpruned to provide fruiting wood for the following year.

Overcropping can also be avoided by preventing the formation of an excessive number of fruit buds by fairly severe defoliation in the " off " year. So far, most of the trials have been of a preliminary nature, to find the best time for, and extent of, defoliation. At least 80 per cent. of the leaves, or all except the young immature leaves on each spur or shoot, have to be removed to produce any obvious effect. The time at which the operation is done is most important, and defoliations carried out from the middle to the end of May have been found most successful. Recovery is rapid from early defoliations and may actually result in an increased leaf area during the critical period of fruit-bud formation, the very opposite of what is desired. On the other hand, defoliations after May result in a more permanent reduction in leaf area, but seem to be too late to affect the development of fruit buds for the following year. As yet, defoliation has not proved as successful as bud-rubbing or blossom-thinning in controlling biennial bearing, but the results are promising. The use of chemical defoliants would make it more attractive as a practical control measure. This possibility is being investigated, and further work may provide a rapid means of controlled defoliation.

A large part of the recent work on biennial bearing at East Malling has consisted in detailed studies of the growth and general behaviour of " on " and " off " year trees of biennial varieties under the same conditions. Similar observations have been made on treated trees and on trees of regular varieties. It has been found in the " on " year, when blossoming and cropping are excessive, that the leaf area of spurs is relatively small and under these conditions no fruit-bud formation takes place. In the " off " year, when there is no developing crop to support, the spur leaf area is twice as great as in the " on " year, root growth and trunk thickening are greater, and there is abundant formation of fruit buds. The condition of trees in the " on " and in the " off " year is obviously entirely different. Any effective method of controlling biennial bearing has to aim at achieving and maintaining a balance between the different functions of the tree, such as is found naturally in regular bearers. It has been found that bud-rubbing, though it involves the removal of incipient leaves, results in a higher leaf area than is found on blossom-thinned spurs, although no leaves are removed from the latter. Both treatments result in a higher leaf area during the growing season than is found on untreated spurs. This seems to enable treated trees to manufacture sufficient food material in their leaves to allow growth to proceed while a good crop matures, and also fruit buds to form for the following year. Further studies of this nature may give us a better understanding of the underlying causes of the biennial habit and provide foundations for improved methods of control.

Acknowledgement.

The writer would like to express her indebtedness to Dr. L. B. Singh, who commenced these studies on biennial bearing, and whose results, published in the *Journal of Horticultural Science*, Volume 24, 1948, have supplied the basis for this bulletin.

Summary.

Recent research on biennial bearing is summarized, and suggestions are made as to the best methods for reducing biennial bearing in the light of this knowledge.

THE MODEL GARDENS AT BRADBOURNE

By J. H. WALKER

Now that six seasons have passed since these demonstration amateur fruit plots were planted in March, 1944, it is interesting to review the crops produced during that period and see how far the hopes entertained at the beginning are being fulfilled.

Designed to show the great advantage of careful planning in making the best use of a small area, the plots are of a size that could easily be fitted into a quarter-acre garden ; at the same time they contain valuable suggestions for smaller areas, which could be planned along similar lines. The plots are of two sizes, the large one of eleven rods, the two smaller of five rods each, areas easily filled by one or two large Bramley trees, but from which a much more varied and satisfactory crop can be produced.

The aims in planning such a plot are several :

1. To plant a garden which will come into bearing as quickly as possible.
2. To produce ultimately sufficient fruit for the needs of an average family.
3. To produce a wide variety of fruit of good quality.
4. To provide a succession of fresh fruit for the table during as many months of the year as possible, using only simple storage, and to satisfy as far as possible the requirements of the kitchen.
5. To make the routine operations of pruning, spraying and manuring as simple as possible.
6. To eliminate the need for expensive or elaborate equipment.

In order to achieve these aims the following arrangements were made :

1. Adequate but minimum planting distances were used so that a wide variety of fruit could be planted. The close planting of trained trees also helps to keep them within bounds by restricting root growth.

2. The tree fruits are on rootstocks known to induce early cropping coupled with small or moderate tree size. The apples are on M.IX*, the pears on Quince C*, the plums on Common Plum or Common Mussel.

3. Although dwarfing rootstocks were used, the selection was restricted to compact growing varieties, avoiding vigorous ones such as Bramley's Seedling.

4. Trained forms make it possible to grow many trees in a small space and to make use of walls and fences. In Garden I the apples and pears are all oblique cordons, the apples at two feet apart in the rows, the pears at three feet. Part of one fence is occupied by triple cordon gooseberries. In Garden II the apples and pears are dwarf pyramids ; one fence is completely covered by U-cordon red currants and gooseberries. In Garden III one fence is occupied by oblique cordon pears.

5. Summer pruning is used as a valuable means of restricting tree size while helping to induce early cropping. The cordon and dwarf pyramid apples and pears are pruned by the methods found from previous experimental work here to be the most successful, both for tip-bearing and spur-bearing varieties. On the cordons primary laterals are cut back to three leaves above the basal cluster when the base of the shoot becomes woody, about mid-July, and secondary laterals arising from them are cut to one leaf above the basal cluster ; in some seasons it is necessary to repeat this in September, and any shoots still soft at the base at this time are cut right out. Gooseberry and red currant cordons are pruned by pinching all shoots back to two inches with the thumbnail as they grow in early summer.

Dwarf pyramids, apart from the central leader which is cut back to eight inches of new wood in winter, are also summer pruned, shortening branch leaders to five leaves in mid-July, and pruning laterals in the same way as on cordons.

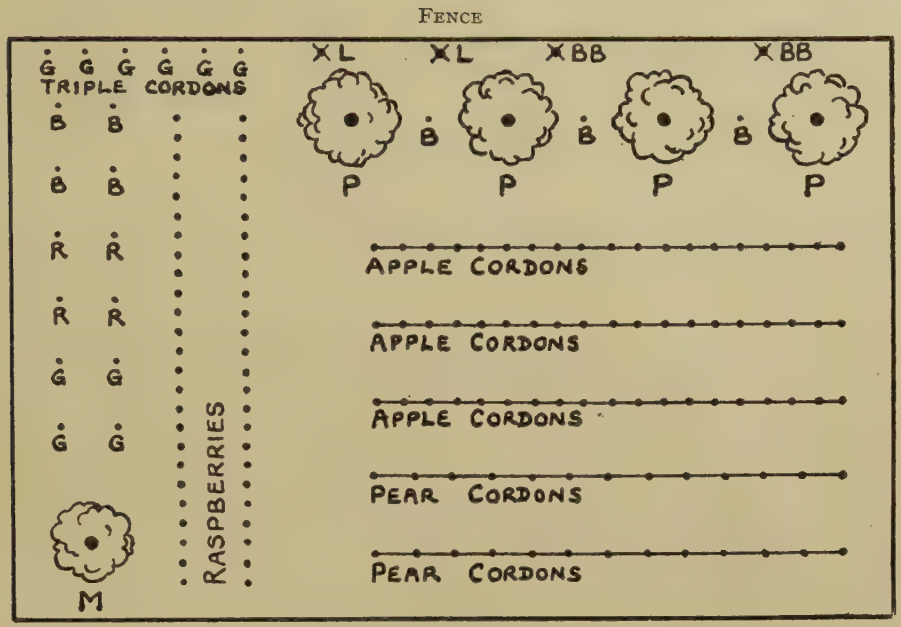
6. Thinning of apples, pears, plums and gooseberries is practised to obtain fruit of satisfactory size.

Description.

It will be seen from the plans of the three gardens (Diagram 1), that the first contains two rows of cordon pears, in eight varieties, ripening over a period of more than five months, and three rows of cordon apples in seventeen varieties whose season extends over nine or ten months.

The cordons were planted at an angle of 45°, a practice that makes it easier to control growth and encourage fruitfulness, with the scion on the upper side of the union. They are supported on a system of wiring using stayed angle-iron posts 6 ft. 6 in. high, set in concrete, with wires at 2 ft., 3 ft. 6 in., 5 ft. and 6 ft. above ground stretched between them by means of straining bolts. There is one additional post in the centre of each 40 ft. row. Canes were fixed to the leeward side of the wires at 45° and the trees tied to the canes. Some of the trees having reached the top wire, all were lowered about 5° in spring, 1949.

* On thin or light soils a somewhat more vigorous rootstock such as M.VII or M.II would be advisable for apples, Quince A for pears.

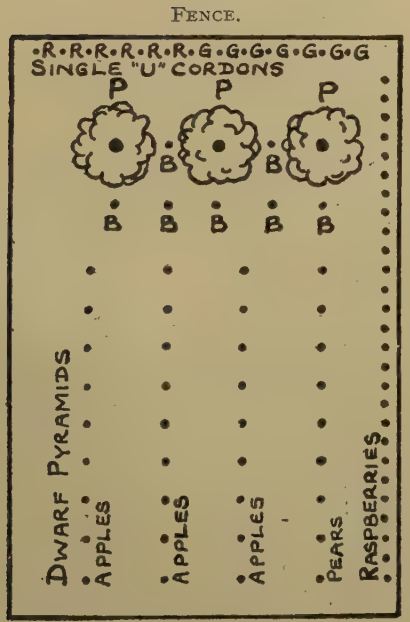


GARDEN I.
45 ft. × 68 ft.

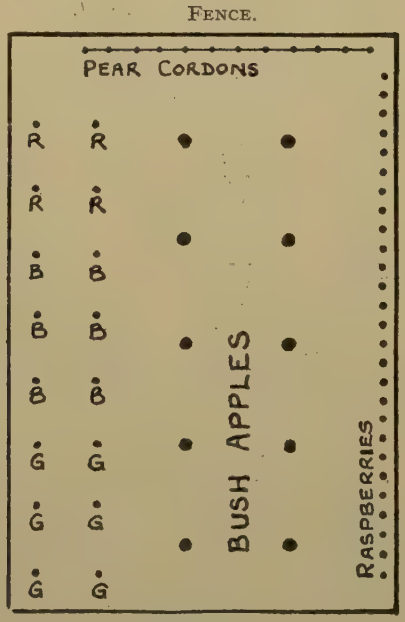
Key :

R—Red Currant.
G—Gooseberry.
B—Black Currant.
BB—Blackberry
M—Morello.
P—Plum.
L—Loganberry.
●=Raspberry.

Scale ft.
0 3 6 9 12



GARDEN II.
45 ft. × 30 ft.



GARDEN III.
45 ft. × 30 ft.

[*Diagrams by Miss E. C. Thompson.*

Three of the plums shown on the plan are half standards on Common Plum ; the fourth, a damson on Common Mussel, was unavailable when the gardens were made, but after various misadventures has now been planted.

The raspberries could not be planted in 1944, but were added more recently, Malling Exploit one year later than Malling Promise. Some of the black currants were planted near the plums because of their similar manurial requirements. The original blackberry on the fence, a Himalaya Berry, has been replaced by Merton Early, a more suitable variety, less rampant and of high quality.

In the second garden the apples and pears are grown as dwarf pyramids. This method eliminates the necessity for the expensive posts and wiring needed by cordons and is more suitable for short rows. The pears are unsupported, but apples on M. IX need at least one supporting wire strained between short posts, because this stock has brittle roots. Two fences are employed for training fruit in this garden ; the row of raspberries is planted alongside one and tied to it, U-cordon gooseberries and red currants are trained on the other.

The third garden was laid out with a view to simplicity of planting and maintenance and to keep down initial outlay. In this the plums are omitted and the apples are planted at 8 × 8 ft. as dwarf bushes on M.IX and are winter pruned. The pears are oblique cordons on the fence ; all the currants and gooseberries are grown as bushes, the latter being stooled (i.e. not grown on a leg).

As will be seen from the plans, the different fruits are segregated as far as possible. This, one of the advantages of planning the plot from the start, is of double benefit. First it simplifies spraying operations, allowing each fruit to be sprayed at the correct time and with the correct material without too much damage to neighbouring trees and bushes, provided spraying is not attempted on very windy days. The " Minimum Routine Spray Programme " shown in Table I has been used and supplemented as necessary. Secondly, it allows some scope for manuring with due regard to the special needs of each fruit.

Table I.

Minimum Routine Spray Programme.

Month.	Fruits to be Sprayed.	*Stage for Application.	Material per 2½ gallons.	Pests and Diseases controlled.
1. December to mid-February.. ..	Apples, pears, plums, damsons, cherries, currants, gooseberries, raspberries and loganberries. Peaches, apricots and nectarines (before Christmas).	Dormant.	†Tar oil winter wash at makers' recommended strength, usually one pint.	Aphides, Sucker and Scales.
2. Early April ..	Apples Pears Blackcurrants Gooseberries	" Green cluster " " White bud " " Grape " " Early flower "	Lime-sulphur ½ pint + DDT (2 oz. of 20% wettable powder).	Scab, Mildew, Caterpillar, Capsid, Big Bud Mite, American Gooseberry Mildew.
3. End April ..	Apples Pears	" Pink bud " " Petal-fall "	‡Lime-sulphur ½ pint.	Scab and Mildew.
4. End May ..	Apples	" Petal-fall "	‡Lime-sulphur ½ pint.	Scab and Mildew.
5. Mid-June ..	Apples and pears	" Fruitlet "	§Lead arsenate ¾-1 oz.	Codling Moth and indirectly Brown Rot.
6. June	Raspberries and loganberries	Pink fruit	Derris, 1 oz.	Raspberry beetle.

* Illustrations of these stages appear in Bulletin 137, *Fruit Bud Development*, of the Ministry of Agriculture, price 2s.

† DNC Petroleum winter wash (¾-1 pint) can be substituted for tar oil on apples and plums where Red Spider is troublesome. In this case the wash should be delayed till February or even early March, provided the buds on trees to be sprayed are still dormant.

‡ Dispersible Sulphur, Colloidal Sulphur or an organic mercurial spray may be used on lime-sulphur-shy varieties of apples or pears instead of lime-sulphur.

§ *Warning.* Lead arsenate should not be used where there is a risk of the poisonous deposit falling on soft fruit, salads or green vegetables.

The manures applied have been mostly organic. Annual applications of meat and bone meal, up to 3 oz. per sq. yd., have been made to supply nitrogen and phosphate. Mulches of farmyard manure in addition have been given to all soft fruit in 1946, raspberries in 1945, 1948 and 1949, gooseberries in 1948 and 1949, black currants and plums in 1949, and to any of the trees showing unsatisfactory growth. Potash was supplied by dressings of wood ashes up to 1947, by sulphate of potash at 2 oz. per sq. yd. in 1948 and at ¾ oz. per sq. yd. in 1949, applied over the whole plots. Extra was given on occasion to a few gooseberries and dessert apples that were showing marginal leaf scorch, a symptom of potash deficiency.

Growth on the whole has been strong enough without being over-vigorous, but the dwarf bush apples are not making enough growth and will need more generous manuring.

Cropping.

Table II gives a summary of the crops from these gardens during the past five seasons. When it is realized that in 1949 the large garden produced 6½ cwt. of fruit at six years old, whilst Garden II, of

TABLE II.

THE CROPS FROM THE DEMONSTRATION GARDENS.
(*Weight in Pounds*)

	1945.		1946.		1947.		1948.		1949.	
Garden I.										
Apples	38·1		107·8		102·2		216·1		365·5	
Pears	25·4		5·7		11·4		11·6		132·5	
Plums	—		1·5		·9		23·2		74·6	
Morellos	—		—		—		—		—	
Total top fruit		63·5		115·0		114·5		250·9		572·6
Black Currants	4·5		14·0		16·4		13·0		28·8	
Red Currants	1·0		—		5·9		14·2		23·2	
Gooseberries, Green ..	3·1		—		·5		6·3		6·7	
Gooseberries, Ripe ..	2·2		—		11·2		9·6		24·8	
Raspberries	—		—		—		—		66·2	
Loganberries	—		3·8		—		—		3·7	
Total soft fruit ..		10·8*		17·8*		34·0		42·1		153·4
TOTAL, ALL FRUIT ..		**74·3***		**132·8***		**148·5**		**293·0**		**726·0**
Garden II.										
Apples	5·7		24·5		66·1		86·1		140·9	
Pears	4·0		1·0		0·4		5·4		33·0	
Plums	0·0		0·8		2·2		8·3		57·0	
Total top fruit		9·7		26·3		68·7		99·8		230·9
Black Currants	5·1		18·75		24·5		21·3		40·3	
Red Currants	—		—		5·8		10·2		11·0	
Gooseberries, Green ..	0·4		—		6·0		2·5		6·1	
Gooseberries, Ripe ..	—		—		8·4		7·0		15·1	
Raspberries	—		19·5		26·8		35·1		34·5	
Total soft fruit ..		5·5*		38·3*		71·5		76·1		107·0
TOTAL, ALL FRUIT ..		**15·2***		**64·6***		**140·2**		**175·9**		**337·9**
Garden III.										
Apples	0·0		5·6		28·8		36·9		69·2	
Pears	3·0		5·0		2·4		7·1		13·9	
Total top fruit		3·0		10·6		31·2		47·0		83·1
Black Currants	4·5		13·3		14·4		9·8		25·1	
Red Currants	1·2		0·0		3·8		15·4		15·6	
Gooseberries, Green ..	4·0		0·0		1·9		2·9		2·9	
Gooseberries, Ripe ..	2·1		0·0		6·1		8·2		19·3	
Raspberries	0·0		9·3		26·7		34·7		30·6	
Total soft fruit ..		11·8		22·6		52·9		71·0		93·5
TOTAL, ALL FRUIT ..		**14·8**		**33·2**		**84·1**		**118·0**		**176·6**

* Plus Strawberries.

only five rods, produced 3 cwt., it may well be considered that the claims made at their conception were justified.

The apple crop in Garden I has increased from 38 lb. in 1945, almost all Egremont Russet and Cox, to the very satisfactory figure of 365 lb. in 1949, including two bushels of Cox. This works out at an average of 6·4 lb. per cordon, all good sized fruit as a result of thinning to singles. In the second garden also, with its dwarf pyramid apples and pears, the yield has been satisfactory. The fact that these have produced somewhat less per tree than the cordons in Garden I cannot necessarily be attributed to the different method of training, as the conditions are not identical in these two gardens ; on the whole, the crops have been proportional to their size. Garden III is giving less as yet : this is inevitable in the early years, though the apple crop may ultimately be as large as that from Garden II. In each of the two smaller gardens one apple tree, not available originally, has recently been planted.

Table III.

Seasonal Supply of Fruit in 1949-50.

Date of Picking in the Case of Soft Fruit, Season of Use in the Case of Apples and Pears

	Garden I.	Garden II.	Garden III.
June	21 lb. Green gooseberries, Raspberries	9 lb. Green gooseberries, Raspberries	4 lb. Green gooseberries, Raspberries
July	133 lb. Gooseberries, Black Currants, Red Currants, Raspberries, Loganberries	105 lb. Gooseberries, Black Currants, Red Currants, Raspberries, Plums	89 lb. Gooseberries, Black Currants, Red Currants, Raspberries
August	51 lb. Plums, Apples, Pears	33 lb. Gooseberries, Plums	5 lb. Apples, Pears
September	76 lb. Plums, Apples, Pears	32 lb. Plums, Apples, Pears	9 lb. Apples, Pears
October-December	232 lb. Dessert apples (inc. 79 lb. Cox) 8 lb. Culinary apples 120 lb. Pears (inc. 80 lb. Conference) Total 360 lb.	69 lb. Dessert apples 9 lb. Culinary apples 30 lb. Pears 108 lb.	34 lb. Dessert apples nil Culinary apples 11 lb. Pears 45 lb.
After Christmas	55 lb. Dessert apples 31 lb. Culinary apples Total 86 lb.	17 lb. Dessert apples 35 lb. Culinary apples 52 lb.	15 lb. Dessert apples 11 lb. Culinary apples 26 lb.

Of the apple varieties, Egremont Russet has given the best yield, a total over five years of 25½ lb. per cordon, 21 lb. per dwarf pyramid, and 31 lb. per dwarf bush. Other varieties deserving of mention for their cropping are Ribston Pippin, particularly as a cordon ; Lord Lambourne, the heaviest cropper in 1949, with 13 lb. per cordon and 16 lb. on a dwarf bush ; Epicure, Wagener, Arthur Turner, James Grieve and Lane's Prince Albert. Edward VII has cropped heavily as a dwarf pyramid and dwarf bush, but not so well as a cordon. King's Acre Pippin and Orleans Reinette produced only a few fruits for the first three years but have given good crops since. Cox has shown up well as a cordon and dwarf pyramid. The only variety to be really disappointing is Stirling Castle, doubtless due to the difficulty of avoiding spray drift on this very sulphur-shy variety.

Pears, more liable to damage from cold and frost, and always somewhat slower to begin bearing, have carried their first heavy crop in 1949 with 132 lb. from Garden I, averaging 5·1 lb. per cordon ; 80 lb. of these were borne by five trees of Conference. During the previous four years the 26 pear trees had produced a total of only 55 lb. The only other varieties to give appreciable yields have been Williams' , Laxton's Superb, Fondante d'Automne and Durondeau.

Table IV.

List of Varieties in Gardens.

	Garden I. 45 ft. × 68 ft.	Garden II. 45 ft. × 30 ft.	Garden III. 45 ft. × 30 ft.
Raspberry (·) ..	18 *in.* × 5 *ft.* Malling Promise Malling Exploit	18 *in.* × 5 *ft.* ½ row each. Malling Promise Malling Enterprise	18 *in.* × 5 *ft.* ½ row each. Malling Enterprise Malling Landmark
Black Currant (B)	*Bushes*, 4 *ft.* × 5 *ft.* Seabrook's Goliath Baldwin	*Bushes*, 4 *ft.* × 5 *ft.* Seabrook's Baldwin	*Bushes*, 4 *ft.* × 5 *ft.* Goliath Baldwin
Red Currant (R)	*Bushes*, 4 *ft.* × 5 *ft.* Skinner's Early Chenonceau Laxton's No. 1	*U-cordons*, 2 *ft. apart.* Skinner's Early Chenonceau La Constante Wilson's Long Bunch	*Bushes*, 4 *ft.* × 5 *ft.* Skinner's Early Laxton's No. 1
Gooseberry (G)	*Bushes*, 4 *ft.* × 5 *ft.* *Triple Cordons*, 3 *ft. apart.* Gunner Leader Leveller Keepsake Cousen's Seedling Howard's Lancer White Lion	*U-cordons*, 2 *ft. apart.* Gunner Lancashire Lad Leader May Duke Lord Derby White Lion	*Bushes*, 4 *ft.* × 5 *ft.* Gunner Lancashire Lad Leveller Keepsake Cousen's Seedling Howard's Lancer
Apples (Culinary) ..	*Cordons*, 2 *ft. apart.* Arthur Turner Rev. Wilks Stirling Castle Lane's Prince Albert Edward VII	*Dwarf Pyramids*, 3 *ft.* × 6 *ft.* Early Victoria Rev. Wilks Lane's Prince Albert Edward VII	*Dwarf Bushes*, 8 *ft.* × 8 *ft.* Early Victoria Lane's Prince Albert Edward VII
(Dessert) ..	Owen Thomas Epicure St. Edmund's Russet James Grieve Fortune Lord Lambourne Ribston Pippin Egremont Russet Cox's Orange Pippin Orleans Reinette King's Acre Pippin Wagener	James Grieve Ribston Pippin Egremont Russet Cox's Orange Pippin King's Acre Pippin	Owen Thomas James Grieve Lord Lambourne Egremont Russet Cox's Orange Pippin Orleans Reinette King's Acre Pippin
Pears	*Cordons*, 3 *ft. apart.* Doyenné d'Eté Laxton's Superb Williams' Bon Chrétien Beurré Superfin Fondante d'Automne Durondeau Conference Thompson's Doyenné du Comice	*Dwarf Pyramids*, 3 *ft.* × 6 *ft.* Laxton's Superb Williams' Bon Chrétien Fondante d'Automne Conference Doyenné du Comice ..	*Cordons*, 2 *ft. apart.* Laxton's Superb Fondante d'Automne Conference Thompson's Doyenné du Comice
Plums (P) ..	*Half-Standards*, 12 *ft. apart.* Victoria Denniston's Superb Gage Golden Transparent Gage Frogmore Damson (on Common Mussel)	*Half-Standards*, 10 *ft. apart.* Early Laxton (on Common Mussel) Victoria Denniston's Superb Gage	
Cherry (M) ..	Morello		
Blackberry (BB)	Merton Early		
Loganberry (L)	Loganberry (true)		

The plums, as might be expected, produced very little till six years old, but in 1949 set a crop sufficiently large to need thinning. From Garden I, 49 lb. of Victoria, 18 lb. of Denniston's Superb Gage and 11 lb. of Golden Transparent Gage were picked ; from Garden II, 36 lb. of Victoria, 9 lb. of Denniston's and 13 lb. of Early Laxton.

Soft fruit yields from each garden have, on the whole, been sufficient for the needs of an average family.

Raspberries yielded satisfactorily in 1949 ; this was their first full crop, as some of the varieties were planted quite recently. They averaged about 2½ lb. per yard run. Malling Enterprise gave only about half the crop of Malling Promise, Exploit or Landmark from the same length of row. Enterprise is ready for picking at the same season as Landmark, and Promise as Exploit, so that a better combination in the gardens would be Promise or Exploit with Landmark.

Black currants gave 4 to 6 lb. per bush in 1949. Differences between the yields of the three varieties have not been marked.

Laxton's No. 1 has been outstanding amongst the red currants, yielding about 6 lb. per bush in 1948 and 1949. The value of planting others is at the moment rather doubtful, though admittedly they extend the picking season. The late variety La Constante has cropped well as a U-cordon, over 3 lb. in 1948 and 2½ lb. in 1949.

The best croppers among the gooseberries were the high quality " white " varieties, Howard's Lancer (late mid-season) and White Lion (late). Both these varieties were being picked until 6th August in 1949. Gunner (early, olive green) and Keepsake (mid-season, green) also gave good crops. It is of interest that one of the triple cordons yielded as much as the heaviest cropping bush at six years old. In 1949 the average crop from the triple cordons in Garden I was 3¾ lb., from the U-cordons in Garden II, 2 lb., and from the bushes (some of them replacements of bushes lost mainly through the Honey Fungus, *Armillaria mellea*) in Gardens I and III, 3 lb. These figures refer to ripe fruit in each case, and do not take into account fruit picked in thinning and used for cooking. In thinning, fruits to ripen were left 2 to 3 in. apart. Some families might, of course, prefer to use a larger proportion for cooking green.

The loganberry crop was lost for two years because all the fruiting canes were killed by winter cold.

Strawberries were grown temporarily in two of the gardens, to occupy space until suitable disease-free raspberries were available, but it is not considered desirable to keep them permanently in the fruit garden as they need replanting every three years and are liable to be damaged by sprays put on the other fruits. Therefore they find a more satisfactory home in the rotational cropping in the vegetable garden.

A further examination of the crops from these gardens has been made in Table III, in which they have been arranged as far as possible to show the spread of produce through the season. To some extent such divisions must be arbitrary. The season begins at the end of May when the first gooseberry thinnings are available, and lasts till May, as Wagener apples from these gardens have been kept without shrivelling in an ordinary house till May ; when the trees are mature they may keep even longer. Wagener is, of course, a good dual-purpose variety. Strawberries, grown elsewhere, could add considerably to the total of fruit available in June.

The slightly lower production in August, the usual period for holidays away from home, might well suit the average family, but although the majority of soft fruit varieties ripen in July, a little care in choosing suitable varieties could increase the August crop and decrease the July one.

If indeed there is any appreciable lack of balance it is in the proportion of after-Christmas dessert apples, most valuable during the period when they are the only fresh home-grown fruit available. In planting a similar garden consideration should certainly be given to increasing the number of late dessert varieties, such as King's Acre Pippin, Belle de Boskoop, Late Orange and Wagener, as the large number of trees in Gardens I and II permits of considerable flexibility.

Table IV lists the varieties of fruit planted in these gardens ; although these include many excellent ones that would find a place in any collection, the final choice is always a matter of personal taste and requirements.

Summary.

A review of the cropping of the amateur demonstration gardens at Bradbourne, with references to the original aims and the methods employed.

STRAWBERRY CULTIVATION*

By W. S. ROGERS

The strawberry is unique among our commercial fruit plants in giving the quickest return on capital outlay and in providing the first fruit of the season. Its delicious flavour ensures that it is always in demand, both as fresh fruit and for preserving, quite apart from the fact that it is among the richest in vitamin C.

These advantages, however, are accompanied by difficulties and problems, which make the successful growing of strawberries a challenge both to the grower and the research worker. The striving for perfection in strawberry growing, as in life, is quite an obstacle race. The more we know and understand the obstacles, the better we can overcome them. Research on strawberry problems by many workers at East Malling and elsewhere has added greatly to our knowledge of the problems.

Choice of Soil and Site.—While strawberries will grow well in almost any soil that is in good heart, one of the unique features of the strawberry plant, its small size (compared with other fruits), makes it especially important to choose frost-free sites. Cold air sinks to the lowest spots, therefore choose a site on a slope, if possible. Frost pockets are suitable for runner beds, however.

Choice of Stock.—Success or failure in strawberry growing begins in the runner bed. Avoidance of virus diseases is of primary importance ; it is now known that the two serious forms, Yellow-Edge and Severe Crinkle, are complex in origin, each consisting of two or more viruses combined in the plant. These viruses pass from an infected plant to all its runners, and are spread in nature by the strawberry aphis.

An important practical point is that strawberry varieties differ in their reaction to virus infection. Some show symptoms clearly and quickly, after infection ; these are called " virus-sensitive ". This class includes Royal Sovereign and Paxton. Others, like Huxley, Perle de Prague and Mme Lefebvre, can be infected with certain viruses without showing symptoms. No perfectly virus-free plants of these, or of some of the Cambridge seedlings, have been found. These are called " virus-tolerant ". They may break down eventually, however, with certain virus combinations. Some varieties, like Auchincruive Climax and Tardive de Léopold, and certain Cambridge seedlings, fall into an intermediate group. There is no sharp line between these groups, and even the " sensitives " may have their symptoms masked in hot, dry weather, but the practical moral, demonstrated over and over again, is that " sensitives " do best when kept apart from " tolerants ". Climax is an exception, a virus-free semi-tolerant, and virus-free clones of it are likely to do well with Sovereign, and will also stand up to Huxley or Perle de Prague as neighbours, in cropping beds.

But, in runner production, for greatest safety, each variety needs to be kept apart.

Special Stocks.—The Special Stock Certificate scheme of the Ministry of Agriculture has contributed greatly to the provision of reliable plants with a minimum virus content. In this scheme runner raising is kept quite separate from fruiting—an important point—and specially selected clones, tested both for virus content and for pomological performance, are the only plants accepted. The runner beds, arranged on the isolated block system, are raised in isolation of at least a mile from fruiting plantations, to minimize risk of re-infection, and in general this has worked well.

Unfortunately, the last two years have been exceptionally favourable for virus spread and, even in Special Stock runner beds, an unsatisfactory amount of virus infection has occurred. For this reason, it was planned to replace the M.40 stock of Royal Sovereign with a new one, M.47, freshly worked up from virus-tested plants, this autumn. Three separate beds were raised, all in situations that appeared most promising. By a stroke of ill luck, severe virus infection spread to all of them—to the last one so late in the season that the normal October inspection had been completed and the plants approved and allotted before the virus symptoms appeared. Under these circumstances, the Ministry decided, rightly in my opinion, that rather than issue stock that would probably show further virus breakdown, they would withhold it. As the M.40 stock also may not reach the high standard required, no Royal Sovereigns will be accepted for the S.S. certificate in 1950.

We shall work up a new stock as soon as possible. This setback stresses the need to go ahead quickly with the establishment of a Nuclear Stock Centre, in which all plants which are subject to virus diseases can be raised under the best possible conditions of disease and pest control. When this centre gets going, it is hoped that it will be possible to issue new parent stocks each year.

* Condensed from a lecture given at the N.A.A.S. Soft Fruit Conference, Lincoln, 9th November, 1949.

Aphid Control.—There is hope of better aphid control with some of the new phosphorus insecticides which may replace the need for nicotine vaporizing apparatus. HETP, Parathion and Pestox 3 have given useful control of strawberry aphid on certain plots this year. Parathion and Pestox 3 must not, of course, be applied to fruiting beds later than blossom time. The makers' instructions should be carefully followed. Dr. Dicker stresses that, with Parathion, it is important to spray thoroughly, using about 500 gallons per acre.

Isolated Blocks.—The Isolated Block System of runner laying has proved valuable in enabling late roguing of plant beds, after the runners have entwined. Experience has shown that, in many cases, it pays to space the plants more widely than originally recommended. Blocks planted at 4 ft. by 8 ft., containing four or six plants with 4 ft. alleys between them, have proved very suitable on good land. The late runners are allowed to spread 1 ft. outside the parents by September, leaving a 2 ft. clear alley, thus occupying 62 per cent. of the land.

Varieties.—Huxley still remains the predominant variety, and in 1948 comprised 72 per cent. of the certified runner beds, but its hard core makes it desirable that we should replace it as soon as possible. I consider that *Auchincruive Climax* may prove to be a suitable substitute. At East Malling we have found it to crop, in several (though not quite all) cases, more heavily than Huxley ; its quality is much better, and it is resistant to red core. Both Huxley and Climax suffer about equally from *Verticillium* Wilt. Climax is more liable to Tarsonemid Mite damage, but this pest should be controllable at the outset by the use of isolated runner beds, and warm water treatment of runners if infection occurs. Climax is a little later than Huxley, under our conditions. The production of autumn flowers by Climax is a prominent feature, and in some years it ripens autumn fruits. Curiously, this does not seem to affect its capacity to crop heavily in the following season. A virus-free tested Special Stock clone, M.46, is available.

Perle de Prague is a promising early variety of good quality. In several trials we have found it just as early as Mme. Lefebvre, and a much heavier cropper. It is highly virus-tolerant, but a tested clone, M.45, containing only Mild Crinkle, is available. While its earliest blossoms may get frosted, it still seems able to bear a good crop, though its late fruits, like those of most other varieties, are relatively small. I would strongly recommend growers to give this clone (M.45) a trial.

Royal Sovereign is still the king of our strawberries, in my opinion. Where it can be grown in reasonable isolation, it does very well. It is safe enough to plant virus-tested Climax near it, to prolong the season. For the more congested strawberry areas my own choice would be Perle de Prague and Climax, for a good succession.

Clones of a number of other varieties are now under test at East Malling Research Station. Bradley Cross did well in the droughty summer of 1949. Oberschlesien M.42 has not shown up well in later trials, and, in view of its other drawbacks, such as the need for cross pollination, I do not recommend it. Huxley and Climax fill its place quite effectively.

Planting, Spacing and Matted Rows.—An important point for the planter to remember is that the strawberry is leafy and succulent all the year round. There is no complete dormancy. Hence, it needs more rapid and careful handling in transplanting than any other fruit plant. It is a mistake to get runners from very far away, unless very rapid transport can be ensured. Our experiments have shown the value of early planting. Strawberry roots make little or no growth when the soil is cooler than 45° F., so the cold winter months are less satisfactory than autumn or spring.

Matted rows have given heavier crops than spaced rows, with Royal Sovereign. In a repetition of the experiment using Huxley, in 1949 matted rows and beds suffered from severe wilting. This shows that under such dry conditions as we had that summer, it is dangerous to get the plants very crowded. Nevertheless, the matted row system seems worth further trial for all varieties. We are testing planting the parent plants at three feet square, and laying the runners in the row. This uses only half the normal number of plants, and still gives a well-filled row. The effect on crop weight is yet to be seen.

Frost.—Even on sloping areas, the strawberry is liable to be caught in shallow cold winds, the so-called katabatic winds, on calm, clear nights. We have shown that a strawed field is more liable to frost damage than one not strawed. This is mainly because the straw insulates the blossoms from the heat stored in the ground, while leaving them fully exposed to loss of heat by radiation to the sky. Strawing is very desirable to keep the fruit clean, but it should be applied as late as possible. Straw placed *over* the blossoms at nights gives considerable protection ; but it must be removed by day, so is not practicable on a large scale. Varieties whose blossoms are partly sheltered by leaves are less liable to frost damage than those whose blossoms are fully exposed.

Irrigation.—In the dry summer of 1949, when strawberry plants wilted, irrigation naturally had a big effect in crop improvement. We have always got an increase in crop from watering strawberries, and, in general, it is worth while after a rainless period of two weeks in or near the fruiting season. Not less than half an inch of water should be given at an application.

The variety Huxley suffered particularly severely from the 1949 drought. Probably it is owing to the good soil moisture conditions of the Wisbech area that Huxley has cropped so well there. Under that year's dry conditions, Tardive de Léopold has cropped better than other varieties on our plots ; but its other drawbacks, such as need of cross pollination and lateness of ripening, make it undesirable for main crop purposes.

Verticillium Wilt.—This disease, caused by a soil fungus, has been very troublesome this year. Dr. Keyworth is working on it, but so far has found no effective treatment, nor any very resistant variety. Fortunately, its severity seems to vary from year to year, and a field that is affected this year may grow away well next year. Therefore, if not too bad, it can be gapped up and kept. This trouble is most serious in runner beds, as it makes effective roguing for virus very difficult, and greatly reduces runner production. Our new stock of the variety Jucunda was particularly severely affected this year, and it is probably owing to this disease that this variety, so popular with the jammers, passed out of cultivation in England.

Eelworm.—The damage caused by strawberry eelworm has now come more to the fore. Mr. Reid has pointed out that eelworms can damage the blossom trusses and cause blind plants or reduced crops. This can be a serious matter. Severely infected plants can be rogued out from runner beds by inspection. The feeding areas of the eelworms can be seen on the leaves by close examination, and the crinkled appearance of the badly affected leaves is typical. Dr. Pitcher is now working on this pest, and is looking for methods of entirely controlling eelworm on runners before planting. Meanwhile, as with Tarsonemid Mite, careful selection and choice of clean planting material is a very useful measure. Warm water treatment for 20 minutes at 110° F. certainly lessens the infestation but does not give 100 per cent. control.

I have omitted some aspects of strawberry growing, to give space to recent developments. To anyone requiring a reference handbook, I would strongly recommend the Ministry's bulletin, No. 95, *Strawberries*.

In view of the recent spread of virus, the coming season may be a difficult one. I would stress that it is only by starting with clean, tested material, keeping a sharp look out for pests and diseases, and making full use of what knowledge is now available, that we can expect results that are both profitable and satisfying.

Summary.

Latest developments are reviewed. Special stocks of the varieties Perle de Prague (early) and Auchincruive Climax (mid-season to late) are recommended and cultural methods for maintaining health and increasing yield are discussed.

SOME ASPECTS OF PROPAGATION RESEARCH, WITH SPECIAL REFERENCE TO FRUIT TREES*

By R. J. GARNER

The use of vegetative propagation in plant nurseries is increasing rather than diminishing, in spite of some geneticists' claim to control the pattern of inheritance, and we look in vain for any reliable evidence that the world-wide investigations by plant propagators will, within a reasonable time, become valueless, redundant or obsolescent.

Even if, taking a simple example, the claim is valid that seedling raspberries come " true enough " for commercial purposes, it is still necessary to raise the plants extremely cheaply if they are to compete with the modern cane nursery producing some 120,000 healthy clonal canes per acre per annum.

The art and science of vegetative propagation having been practised for thousands of years, it is not surprising that research is not often rewarded by startling beneficial discoveries, but only by small accretions or " bricks " of knowledge. However, increase in the number of these bricks will doubtless eventually enable us to construct the house of " Know How ".

At East Malling, Dr. Hatcher and I have laid down an extensive long-term programme of research on vegetative propagation ; at present our main concern is with the propagation of fruit-tree root-stocks.

1. Source of Hardwood Stem Cuttings.

Our practical aim may be simplified to *increasing the productivity of available labour*. The comparatively simple method of propagation by hardwood stem cuttings obviously holds attractive possibilities and our first job has been to investigate the behaviour of hardwood cuttings. This work falls under three main heads, (*a*) source or internal condition when collected, (*b*) treatment between collecting and planting, (*c*) planting and subsequent treatment. We have already published papers on each of these three aspects of our research but, at this moment, I want to give only one example of that very important factor in any propagation by cuttings—the pre-natal history of the cutting, so often neglected by the investigator. This example concerns the *origin* of the mother plant yielding the cutting.

Cuttings of the shy-rooting apple Malling Crab C were collected from parent plants of four classes :

Root propagated, one-year-old.
Root propagated, two-year-old.
Shoot propagated, one-year-old.
Shoot propagated, two-year-old.

The two-year plants had been cut down close to the ground at the end of their first year, but another trial with non-pruned parents confirmed the findings which follow. Whole shoots were collected and one 12 in. cutting was taken from the base, and one from the upper half, of each shoot. The results are shown in Table I.

TABLE I.

BEHAVIOUR OF STEM CUTTINGS IN RELATION TO PARENTAL SOURCE (80 CUTTINGS PER TREATMENT).

	Root-propagated Parents.				Shoot-propagated Parents.			
	One-year-old.		Two-year-old.		One-year-old.		Two-year-old.	
	Apical.	Basal.	Apical.	Basal.	Apical.	Basal.	Apical.	Basal.
Grown cuttings ..	1	17	—	13	—	1	—	14
Living cuttings (not grown) ..	21	60	10	46	7	18	12	30
Total survival ..	22	77	10	59	7	19	12	44

* The substance of a talk given at Wageningen on 19th May, 1949, and reprinted by permission from *Mededelingen Dir. Tuinbouw*, 1949, **12**, 390-3.

It will be seen that root-propagated parents are a better source of stem cuttings than shoot-propagated parents. Furthermore, while one-year root-propagated parents are a better source than two-year root-propagated parents, the reverse is true for the shoot-propagated parents.

2. Budding Technique.

Having given just that one example of the importance of considering the effect of source of cuttings, I will turn to work in the tree-raising nursery.

Though the method of grafting known as shield-budding is universally practised, there are certain technical variations that are of interest. At East Malling we bud our rootstocks with the wood left in the bud shield. Before we conducted our technique trials we invariably removed the wood, but, with apples, pears, plums and cherries, we found no advantage in removing the wood, so we have given up this practice.

We also tried the effect of tying with rubber budding-strips, using raffia as our control. The result was that the number of successful buddings was greater under rubber ties than under raffia, the figures being 92 per cent. for rubber and 79 per cent. for raffia. It seems doubtful if such a difference would be obtained in all cases, but it is probably true that rubber is superior to raffia.

At East Malling, and in some other parts of England, the Red Bud Borer (*Thomasiniana oculiperda* Rübs.) sometimes causes the death of newly inserted buds, particularly of apple. In 1938 we conducted a trial using 1,600 M.IX budded with Cox's Orange Pippin, the wood being left in the bud shield. Half were tied with rubber and half with raffia. Half of each of these batches were smeared with petroleum jelly immediately after tying. The condition of the buds in the following March is shown in Table II.

TABLE II.

EFFECT OF PETROLEUM JELLY SMEAR ON RUBBER AND RAFFIA TIED BUDS.

Conditions of buds in March.

Treatment.	Live Buds %
Rubber + petroleum	99
Raffia + petroleum	98
Rubber alone	73
Raffia alone	41
Rubber alone, on adjacent plot (1,000 buds) ..	87

The take of buds with " raffia " alone is exceptionally low and it seems likely that this treatment failed to prevent some damaging agency. On the result of this and other trials we recommended the use of petroleum jelly wherever unsatisfactory takes of apple buds occurred. Once again it is seen that rubber ties were better than raffia.

Last season (1948) we conducted further trials with petroleum jelly on four varieties of apples. There was a very severe attack of red bud borer and the data summarized in Table III show that the use of petroleum jelly was fully justified.

TABLE III.

EFFECT OF PETROLEUM JELLY SMEAR ON TAKE OF APPLE BUDS.

Variety.	Raffia alone.	Raffia plus Petroleum.
Cox's Orange Pippin	14	65
Worcester Pearmain	58	85
Miller's Seedling	36	83
Tydeman's Early Worcester	44	69

3. Sweet Cherry Trees of Restricted Growth and early cropping.

Following technique trials with pears on quince, double-working in one operation to overcome incompatibility of the breakage type is now standard practice ; Beurré Hardy is recommended for the intermediate.

Our attention has now turned to the wider use of such manipulation in the construction of fruit trees. In plums the ravages of the Bacterial Canker disease (*Pseudomonas mors-prunorum* Wormald) have been reduced by using stems and crotches of varieties resistant to the disease.

Attempts to produce sweet cherry trees of restricted growth and early cropping are of interest but have not yet proved suitable for practical application. We lined out some Malling 12/1 (*P. avium*) and the following June grafted them with 1 in. wide rings of rind of various species six inches above ground level. In July we budded them with a selected sweet variety a few inches above the ring. Thus the trees were " triple-worked " in one season (Fig. 1). In many cases the ring became bridged by 12/1 tissue arising from the stripped surfaces, so vitiating the effect of the ring. Where the ring was complete, the effect upon growth was, in some cases, very pronounced. A modified technique involved grafting at full height with dormant scions instead of budding. These trees, when completed, had 12/1 roots, rings of restriction (*P. mahaleb* or *P. cerasus*), stems of 12/1 (resistant to Bacterial Canker) and heads of the selected scion variety (Fig. 2). Though these particular trees may not prove of commercial value, it is suggested that a wider use of special grafting methods in the construction of fruit trees might have value in particular cases.

Summary.

A summary of the main lines of propagation research at East Malling.

Fig. 1.

Malling F 12/1 (*P. avium*) rootstocks ring-grafted and budded, photographed three years later. Left to right, *P. avium* (F 12/1), *P. cerasus* (Kentish) and *P. mahaleb* ring grafts.

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FIG. 2.

Malling F 12/1 (*P. avium*) rootstocks ring-grafted, preparatory to highworking, photographed three years later. Left to right, *P. avium* (F 12/1), *P. cerasus* (Kentish) and *P. mahaleb* ring grafts.

THIS BROWN ROT PROBLEM

By M. H. MOORE

The 1949 season brought many complaints of the prevalence of infection by the Brown Rot fungus, *Monilia fructigena*, especially in apples, and some growers have reported that the disease has never been more severe in their experience. Evidence shows that 1949 was indeed exceptional in that respect, but there is no reason to suppose that the disease must continue to increase proportionately.

How the Fungus Overwinters.—Sources of infection for 1950 may be plentiful, and whatever can be done to reduce them should be the first line of attack. There are two main sources of fresh spores: mummied fruits and the branch- and spur-cankers. The spore cushions of this common fruit-rotting fungus do not arise in any quantity until June, though they can be found in May. Those of the allied Blossom Wilt fungus (*Monilia cinerea*), however, which also causes fruit rotting in plums and cherries though rarely in apples, arise in winter, usually from December onwards. Tar-oil spraying in January and February is, therefore, effective against the rot caused by the Blossom Wilt fungus but not against the more common fruit-rot.

The precautions to be observed in reducing Brown Rot infection were discussed in the *East Malling Research Station Annual Report for* 1944 (pp.124-26). This stated that during winter pruning a watch should be kept for mummied fruits, dead spurs, and branch cankers. Branch cankers arise where the fungus has grown back from the rotting fruit, through the stalk, into the spur, and then into the branch bearing it; thus they are centred around a spur, and, unlike Apple Cankers (due to a different fungus, *Nectria galligena*), they are smooth, and the affected bark is often a dull brown-red or dirty orange colour, depending to some extent on the apple variety. The mummied fruits should be collected and destroyed or knocked to the ground in the alleys, where they are much less dangerous than on the tree, for many of them break up and disappear during the winter, especially on cultivated land. Another way of dealing with them is being tried at Long Ashton, where R. W. Marsh and R. J. W. Byrde have shown a reduction in the number of spore-cushions produced in summer after treatment of mummied plums and apples with special winter sprays. It is best to burn branch cankers; affected spurs, like mummied fruits, are safer on the ground than on the trees, or, better still, they should be collected and destroyed where possible.

The following account concerns experiments made on apples since the 1944 Report was published. The problem is similar in pears, and so no special mention is made of them.

1. THE PROBLEM IN APPLES.

Is Protective Spraying Likely to Prove Satisfactory?

It may not be possible to destroy all the overwintering sources of infection, and even a few freshly infected fruits in summer could quickly start an epidemic in favourable circumstances. It is, therefore, well to try other suitable means of preventing infection. The fungus readily infects fresh wounds (primary infection), and in the plantation rarely gains entry in any other way (e.g. through an abnormally open eye) except where a healthy, undamaged apple is growing in close contact with a rotting one (contact infection). Protection of fresh wounds in the fruit by applications of fungicide seems an obvious remedy, but experience so far shows it to be an uncertain one. Lime-sulphur and Bordeaux mixture, our standard fungicides, have been used as summer sprays on apples since spraying became part of the routine of growing healthy crops, but Brown Rot nevertheless was, and still is, a problem. We have other fungicides now; are they more likely to solve the problem?

To help to answer this question, experiments were made on Cox's on M.IX at East Malling for two seasons, 1945-46.* The results showed that infection was not reduced by either one or two summer applications of sprays containing phenyl mercury chloride, tetramethylthiuram disulphide, or the dimethyldithiocarbamate of iron or of zinc. More recently, R. J. W. Byrde has shown in a small-scale trial on trees in two isolated rows of Belle de Louvain plum at Reading University that one summer

* A full report on these investigations will shortly be published in *The Journal of Horticultural Science*.

application of phenyl mercury chloride reduced Brown Rot infection by about three-quarters compared with that on unsprayed controls, and 1 per cent. lime-sulphur reduced it by about one-half. As the dilution of phenyl mercury chloride used was the same in the East Malling and Reading experiments, the results appear to be conflicting, though an explanation of the difference may lie in the circumstances of each centre ; for instance, the host plant was not the same in each case. The iron spray (as " Fermate ") was earlier tested with some success by R. W. Marsh and his colleagues on large Cox cordons in Worcestershire. Summer spraying has shown promise also on cherries and peaches in the U.S.A.

For protective fungicides to be successful, every fresh wound in the fruit would appear to need a covering of a spray able to protect it until it is no longer infectible. Where spraying happens to coincide with a peak period of wounding it may show results, but if many wounds become infected before the spray is applied, or if the deposit from a previous spraying has weathered away before many of the wounds are made, the spray is unlikely to be really effective. Success from summer spraying seems at present to be largely a matter of local conditions, and is perhaps best seen where trees are growing in relative isolation. More consistent promise may result if the number of spores in the plantation can first be reduced on a commercial scale, for this is akin to isolation.

What Proportion of the Wounds in the Fruit can be Avoided ?

Meantime, other experiments were made at East Malling from 1946-48* to find out what *proportion* of wounds can be avoided while the fruit is still on the tree. Avoidable wounds are mostly those caused by pests and diseases that can be controlled by spraying ; unavoidable ones are those due to mechanical and similar damage, i.e. to the weather (weather cracking, hailstones, abrasions from branches and laterals etc.) and to birds, wasps, and occasionally other animal agents.

Unavoidable Wounds.—Weather cracking comes about in different ways. Frost damage to the skin of the young fruitlet, or even to the skin covering the basal part of the flower before fertilization, may later be seen on the fruit as russeting. This is a network of very small, corky cracks in the skin, which, because of the damage, has failed to grow fast enough to accommodate the swelling fruitlet. Russeting may be produced, especially in Cox's, not only by certain sprays such as lime-sulphur and copper preparations, but by long exposure to the sun (a form of Sun Scald). As the apple grows towards maturity, and especially at periods when rapid growth occurs, early damage of this kind can be accompanied by larger cracks formed across or near to the russeted areas (" cracked russet "). It is usual to find that the earlier the first damage, the greater the resulting distortion, and the more extensive the later cracking. Sometimes cracking occurs where little or no russeting can be seen ; this often follows rain when the fruits have been toughened by drought.

Some of these larger cracks, like the very small ones, become sealed with corky tissue produced by the apples, especially cracks formed before late June when the Brown Rot fungus produces its spore-cushions freely from the over-wintered sources. Later, when the orchard air is well charged with Brown Rot spores, such fresh wounds are likely to become infected before they can be sealed. This commonly occurred in 1949, and, in addition, the long period of dry, hot weather led to formidable attacks on the growing apples by birds, notably tits, possibly seeking moisture. Wasps also did much damage.

Some good may result from destroying wasps, nests and using bird-scaring devices, but on the whole it is difficult to see how most wounds of this kind, and those from occasional hailstorms, wind bruising, etc., can be avoided. They go to make up a basic quota of Brown Rot on every commercial holding, a quota that must vary from year to year and farm to farm according to the conditions.

Avoidable Wounds.—Wounds that arise through an attack of insect pests (other than wasps) or fungus diseases are a different matter ; they can largely be avoided by careful attention to the spray programme. Cracking such as that already described may occur where early-established Scab-spots are formed on the skin ; the effect is similar, although the cause may be different. Penetration of the fruits by the caterpillars of the Codling Moth usually occurs from July onwards, when the orchard air is likely to contain innumerable spores of the fungus. These, when dry, are light and powdery, and readily blown about in the breeze. Records show that a noticeable increase in Brown Rot infection follows the onset of the caterpillar activity of this pest.

* A full report on these investigations will shortly be published in *The Journal of Horticultural Science.*

Experiments on the Relative Importance of Avoidable Wounds, 1946-48.

These were made under controlled conditions in the plantation, and involved the use of different spray-programmes. It was considered that the best way to assess unavoidable loss was to attempt to eliminate by spraying all wounds resulting from pest and disease attack ; a complete spray programme was, therefore, applied to one series of trees. Similarly, wounds arising from attacks by Scab, Sawfly, and Codling respectively were allowed free play on other series of trees by omitting in turn from an otherwise complete spray the component normally used for their control. Thus, certain trees received no lime-sulphur for Scab, some no nicotine for Sawfly, and some no arsenate for Codling, making, with the complete spray, four treatments in all. The trees were 12-year-old (in 1946) Cox's on M.IX at 12 ft. square.

The object of these experiments was to test a general principle under one set of controlled conditions ; nevertheless, the results can be taken as a general guide to what the grower can achieve in dealing with his own particular Brown Rot problem.

Over the three seasons, during which there were two wet summers (1946 and 1948) and one very dry one (1947), the average unavoidable rotting on these Cox's on M.IX was about 10 per cent. of the total crop present in July. This figure includes an unduly low allowance for contact infections because, apart from the first year, infected fruits were picked from the trees before the rotting had got very far ; this was done so that the sources of the wounds could be the more accurately recorded. Complete control by spraying of all wound-causing pests and diseases was not expected or achieved, and the 10 per cent. value thus includes a small allowance for rotting from this cause, such as would be found in even the best-sprayed commercial plantations. About two-thirds of the 10 per cent. value came from mechanical and similar damage.

Where Codling sprays were omitted, some 12 per cent. additional rotting occurred, and, with Scab sprays omitted, a further 10 per cent. or so. The omission of a Sawfly spray did not affect the amount of rotting in these experiments ; damage from this source is usually ended before Brown Rot becomes prevalent.

Thus, if Codling and Scab together had not been controlled, some 30 per cent. of the total crop present in July could have been lost from all sources through *primary rotting on the tree*, apart from the losses due to the pests themselves. To this must be added secondary rotting (contact infections), which for the reason stated was artificially reduced in these experiments, together with rotting that occurs after damaged but not yet infected fruits are picked and stored, and it will be appreciated that the total loss can reach formidable proportions. It need hardly be added that a first-class sample of fruit can be ruined for storage by careless handling—wounds from torn-out stalks, from the jabbing of one apple by another's stalk, from finger nails, box bruises, jolting cartage, and such like ; all these are liable to rot and so increase the tally. Such damaged fruits should certainly not be stored.

Fortunately, Codling and Scab can be controlled by intelligent spraying, and the results of these experiments suggest that a grower could thereby avoid roughly two-thirds of the total risk on his trees unless something unusual happens, as in 1949. Clearly, therefore, it is sound economic practice to do so.

Whether Codling or Scab is the chief avoidable wound agent depends much on the seasonal conditions. In a wet season Scab is likely to be at least as important as Codling, and probably more so ; in a dry, warm summer, Codling is evidently much the most important avoidable wound agent the grower has to contend with. From the Brown Rot angle alone, two sprays instead of one for Codling control in such conditions (as given in these experiments) would be well worth while, and entomological advice should be taken as to the best times for applying them.

A Demonstration, 1949.

A further word should be added about the influence of the unusually dry, warm summer of 1949.

When the above experiments ended in 1948, it was thought worth while to get figures from well-sprayed commercial plantations. Results are available from three of these, all Cox's, in 1949, one at East Malling, and two in East Sussex through the co-operation of Mr. W. S. English of the National Agricultural Advisory Service. On the East Malling plot, where the trees were on differing root-stocks, including M.IX, the percentage of rotted fruits was much lower than at the two other centres ; lower even than it was on a Cox plot nearby, where all the trees were on M.IX. As indicated below, the rootstock plays some part, but the importance of local conditions is the chief point derived from these differences. In both instances in Sussex the infection in at least four out of every five rotting apples had started at wounds caused by mechanical and similar damage, mostly from birds and wasps. Bird damage probably varies a great deal with the season, and with the location of the trees in relation to surrounding fruit and the nearness to woodland, inhabited buildings, busy roads etc. ; evidently it was of unusual severity in 1949.

Cracked russet also was specially severe in Cox's. Certain incidental results from Apple Scab experiments on Cox's on M.IX at East Malling showed that cracked russet was responsible for much Brown Rot invasion, and this increased with an increase in cracking. Past experiments have shown that Cox fruits on M.IX are specially prone to russeting and cracking, helped by early frost or by long exposure to sunshine, by a period of drought or sometimes by certain sprays.

2. THE PROBLEM IN PLUMS AND CHERRIES, COBNUTS AND FILBERTS.

With plums and cherries, two points claim special notice : (1) that the Blossom Wilt fungus, as well as the more usual fruit-rotting one, causes a fruit rot, and this tends to increase the total amount of rotting, and (2) that these fruits, especially when intended for dessert, are allowed to soften to eating ripeness on the tree, when they are specially attractive to birds and wasps, and more liable than the hard fruits to be damaged by them. Also, they are usually more prone to cracking as they ripen. Though no records are available, it is thus reasonable to assume that the *proportion* of rotting through unavoidable damage is much higher in plums and cherries than in apples and pears. Like Codling in apples, the boring of the Red Plum Maggot (*Cydia funebrana*) can be an important further means of entry for Brown Rot in plums, and, where troublesome, it should be controlled.

In cobnuts and filberts it has been shown that the Brown Rot fungus gains entry chiefly through egg-laying punctures of the Nut Weevil in the shell before the nut hardens in July, so here also the problem concerns wound agency. In nuts, however, the proportion of avoidable damage is much higher than in plums and cherries, and the problem can be largely disposed of by effective control of Nut Weevil with DDT.

IS THE REMOVAL OF ROTTING FRUITS WORTH WHILE ?

A sidelight on the growers' problem was seen in some inoculation experiments made on cobnuts in a plantation overhung with interplanted apples and plums. Certain nuts were pierced with a needle, and some of these were then inoculated with the Brown Rot fungus (at a rate of about 800 spores per nut). Nevertheless, there was just as much rotting in pierced nuts that were not inoculated, thus showing there were already enough spores in the orchard air without adding any.

Moreover, in the experiments on apples already described, rotting fruits were removed from the trees as they occurred, but this seemed to make little difference to the amount of primary infection that befell later, though it would of course reduce the number of contact infections. The experiments were made on trees in the midst of a fairly large plantation ; rotting fruits were not picked from the surrounding trees, which could, therefore, act as sources of infection for the experimental ones. It is doubtful whether the removal of rotting fruits on any practicable scale would effectively lower the " infection risk " in most commercial plantations, but in small, isolated plantations and gardens, where it is more feasible, it might well repay the trouble.

STORAGE ROTS

A word on storage rots may be timely here because there is a popular tendency to class them all together as " Brown Rot ", a term that is correctly applied in a technical sense only when any one of of the Brown Rot fungi (species of *Monilia*) is responsible. The common Brown Rot fungus can cause rotting in storage, especially in the early stages. An affected fruit may not be brown but black and firm, and may bear no spore-cushions as when rotted in the open. A thick, white felt, or merely wisps of fungus tissue may be present.

The main cause of rotting in storage, however, is Blue Mould (*Penicillium expansum*), which can attack fruits through wounds at all stages of storage, causing a very soft rot. When fruits are ripening in store, and particularly when they are becoming over-ripe, rotting may be due to Bitter Rots (*Glœosporium* spp.), to Grey Mould (*Botrytis* sp.), or to certain other fungi. Blue Mould can then gain entry also through tissue damaged by breakdowns of various kinds or by other rot fungi. The Bitter Rots usually invade through lenticels (breathing-pores) especially when the fruits have passed their best. The rots often follow " lenticel-breakdown ", and they produce light- to medium-brown, circular, sometimes zoned, saucer-shaped or flat and at first moderately firm depressions spreading uniformly but slowly outwards, and eventually running together.

Spores of these storage-rot fungi enter the store chiefly on the fruits, and, except for *Penicillium*, most of them make little headway until the fruits have reached the right condition for infection. Liability to storage rots may depend to some extent on growth conditions in the plantation and their effect on the quality of the fruit, but what these influences are is as yet uncertain. The best preventive is to observe hygienic principles and care in all the necessary operations from picking to storage, which should not be unduly delayed or prolonged. Wrapping also is helpful in isolating diseased from sound fruits. So far no direct method such as spraying or washing with a fungicide, or the use of fungicidal wraps, can be recommended for reducing the incidence of storage rots.

Summary.

This paper is a discussion for fruitgrowers of the general Brown Rot problem, more particularly in apples, with a summary of the findings of recent experiments on control measures.

DISEASES OF HOPS*

By W. G. KEYWORTH and J. PAINE

This paper on the main diseases affecting Hops is divided into two sections covering respectively virus diseases and fungal diseases.

1. Virus Diseases.

This section considers firstly virus diseases in general, secondly the investigational work which has been carried on at the East Malling Research Station and finally the further investigations which are planned.

What is a virus ? The Oxford Dictionary quotes the following four meanings :

i. Physical poison (" virus of the viper ").
ii. Moral poison.
iii. Violent animosity.
iv. The meaning with which this paper is concerned, exemplified by the expression " canine virus ", which refers to rabies.

Viruses are extremely minute, invisible bodies that cause infectious diseases.

Although they are invisible, they are known to exist because (*a*) shadows can be seen by the use of the electron microscope ; (*b*) viruses produce recognizable diseases like foot-and-mouth disease, paralytic rabies, yellow fever and epidemic influenza in animals, and Cauliflower Mosaic, Potato Leaf Roll and Hop Mosaic in plants ; (*c*) the infective principle has been isolated from plants infected with some virus diseases. This infective material may be seen but it is not known to be the pure virus. It has been obtained in the crystalline state and it is thought by some that it may be pure, but the important thing is that this substance, if re-introduced into the healthy plant, produces the typical symptoms of the disease.

Having obtained evidence that there are viruses that cause infectious diseases, the more that is known about their properties before work is started on them, the more likely it is that the research will prosper.

What are these properties ? Viruses cannot multiply except in the living tissues of their hosts, so they cannot be treated like fungi or bacteria which can be grown on plates of agar or other media and identified. How, then, is it known that such viruses cause any particular disease ? By careful examination of the host for a pathogen it is possible to detect the presence of fungi, of bacteria, of insects and of animals. If it is none of these, it may be due to environmental or genetical factors, or it may be an infectious disease. If it is the latter and can be shown to be transmissible, it is called a virus disease.

How do they spread ? There are three ways—mechanically, by grafting and inarching, and by insects. Some consideration of these methods of spread will show the reasons for the experiments now being carried out :

i. *Mechanical Transmission.*—Viruses that are transmitted in this way may be spread by contact between a healthy and a diseased plant. They may also be spread by rubbing a diseased plant on to a healthy plant. Sometimes these two methods do not produce infection. In this case it may be possible to cause infection by grinding the infected plant in a mortar and rubbing the material onto a healthy plant with carborundum. These methods of mechanical transmission are possible with some virus diseases and not with others. For instance, potato X disease is spread in the field by contact of the leaves, but in the case of strawberries and raspberries such transmission has not been achieved. Of the four hop virus diseases only one, Chlorotic disease, has been reported as mechanically transmissible. Another method of demonstrating transmission of the other three had, therefore, to be found.

ii. *Transmission by Grafting.*—The union between diseased and healthy plants allows the virus to pass from one to the other. The infectious nature of all four hop viruses was demonstrated in this way. There are cases in which no transmission is possible by grafting. This is sometimes due to incompatibility, for instance the carrot and the peach tree are incompatible. In this case Dodder, a parasitic plant which was used to link the carrot and peach tree, took the virus from one to the other.

iii. *Transmission by Insects.*—The insect, when feeding on the infected plant, takes up the virus and subsequently when feeding on a healthy plant injects the virus into it. The majority of viruses that have been studied carefully are known to be transmitted in this way.

* The text of a paper read at a conference on Hop Diseases at Hereford on 20th January, 1949, and reprinted by permission from *The Herefordshire Agricultural Journal.*

It is most important to find out what are the vectors—or carriers—of the hop viruses, for with nearly all virus diseases there has been little advance until the vector has been found. For example, the strawberry diseases known as Yellow-edge, Crinkle and Break-down remained mysteries until Dr. Massee discovered that the Strawberry Aphid was the vector. By means of tests with this aphid, Dr. Prentice found that there were at least five viruses concerned. Now, as a result of that work, tests can be made and the state of special stocks determined ; also in controlling these diseases it is possible to rogue and in addition to attack the aphid, which renders control much more effective than roguing alone. But no vector of hop viruses has yet been discovered. Aphids are the common vectors of viruses in England, but a gall mite carries Black Currant " Reversion " and a flea beetle carries Turnip Mosaic. Thus it would be unwise to assume that the Hop Aphid is responsible for carrying the hop viruses.

There are four known virus diseases of hops, Mosaic, Chlorotic disease, Nettlehead and Split Leaf Blotch, and there is always the possibility that further viruses may be discovered while the search for the control of those already known is going on ; some may think that virologists are for ever finding new viruses, while others may have come to the conclusion that virologists are introducing new ones ! But before describing the search for an insect vector, it may be helpful to refer briefly to the history of virus diseases.

In 1892 Ivanovski filtered tobacco juice from mosaic-infected plants and found the filtrate infectious. This was the first demonstration of a plant virus. However, it was not till thirty years ago that the importance of viruses was realized. This does not mean that virus diseases were not known before, for smallpox, a virus disease of man, may have existed in China in 1700 B.C., and did exist in practically all European countries by A.D. 1000. In Holland the famous variegated tulips were described as long ago as 1576 by Carolus Clusius, and were frequently painted at the time of Rembrandt (1650). Now it is known that the variegation known as " breaking " is a virus disease that reduces vigour and is undesirable.

This does not mean that new viruses do not arise from time to time, but that old ones, newly described, appear new. Modern discoveries are due in part to our knowing so much more about plant diseases than in the past ; and to the fact that many of the diseases are more widely distributed than before.

For example, the " degeneration " of the potato was discussed in a paper by Maxwell, an English farmer, in 1757. It was noticed that new seedlings gave a high yield, while progressive deterioration accompanied continued propagation by tubers. It was thus held that " degeneration " was due to continued vegetative propagation. By 1913 it was noticed that " degeneration " could take more than one form, and a distinction was drawn between leaf-roll, mosaic and streak. Then it was discovered that these diseases were caused by viruses, and at the present time about twenty potato viruses have been described and are known to be responsible for the condition that used to be known as " degeneration ".

Another example is *Abutilon striatum* var. *Thompsonii*. This variegated ornamental was introduced from the tropics and described in the *Gardener's Chronicle* in 1868. It is now known that the mottling is caused by a graft-transmissible virus.

The final example is Nettlehead, which has only recently been shown to be graft-transmissible. Yet Charles Whitehead in 1870 described the rotting roots of hops in the old hop gardens of Kent, and this description is very similar to the description of the disease now known as Nettlehead ; and in 1894, at a meeting at Wye College, one hundred farmers complained of the seriousness of Nettlehead ; so this graft-transmissible virus is really an old virus newly described.

The Present Position of Research on Hop Virus Diseases.

Research on hop virus diseases has been carried on at East Malling since 1939, the two main diseases studied being Nettlehead and Mosaic. In addition a number of other disorders have been investigated. Although much of the research work has been done at East Malling, field observations have been made in all hop areas including Herefordshire and Worcestershire, and the object of the research is to cover the requirements of all such areas for disease control.

Nettlehead.

This disease, formerly thought to be caused by eelworms, was shown to be graft-transmissible in 1940 and it is, therefore, almost undoubtedly of a virus nature. The two most characteristic symptoms are the upward rolling of the leaves and the inability of the bines to climb the strings. This latter symptom causes severely affected plants to become very dwarfed in appearance. A typical nettlehead plant is shown in Fig. 1.

Although plants showing these symptoms can easily be recognized, unfortunately symptom masking is very common and this may so easily obscure symptoms that it becomes very difficult to recognize affected plants. This symptom masking is caused by hot weather and is thus of greatest effect in the summer months. For this reason it is most advisable to start roguing for Nettlehead very early in the season, particularly before the bines are trained. At this time the affected plants can be distinguished by the sparse growth of the bines, some of which usually show the typical leaf rolling symptom and are very stiff and upright in appearance. These symptoms are not easily seen after training has occurred and, because of heat-masking, may remain obscured for some time during the summer. In this period, however, the disease may still spread from such plants.

Nothing is as yet known about the method by which Nettlehead spreads in the field, but it has been found that the disease spreads particularly along the rows in Worcester plant, suggesting an insect vector that can more easily move along such rows than across them.

One important feature of the spread of Nettlehead is that newly infected plants do not usually show symptoms until the next year, a fact which increases the difficulty of adequate roguing. It is thus all the more important to remove nettlehead plants as soon as they can be detected.

New evidence has recently been obtained from aerial surveys that demonstrates that Nettlehead is often more frequent on the sites of old hedgerows or former pasture fields. This effect has been suspected by growers for many years, but it has been difficult in the past to obtain clear confirmation of it. Now such confirmation is available it is proposed to study possible causes of these effects. Aerial photographs of such effects are shown in Figs. 2(*a*) and 2 (*b*).

Other large-scale experiments that are now in progress include one on the effect of nitrogen and potash on disease incidence, but to date heavy applications of these manures have not produced any marked effect. Many growers are of the opinion that Nettlehead may persist in the soil. Experiments on this have so far given no evidence that it is so, but a new large-scale experiment has just been laid down in which stock known to be free from disease has been planted on the site of a very badly affected yard and results will be observed over the next three or four years.

Mosaic.

This disease was first shown to be graft-transmissible by Professor Salmon and Dr. Ware. It is of importance only to growers of Goldings, as it is only on these varieties—and certain males—that the disease causes symptoms. These symptoms are the downward curling of the leaves, which become mottled with dark and light green patches, and the dying back of the bine (Fig. 3). The disease is lethal and will kill affected plants in about two years. One of the earliest signs of the disease is a clearing of small lengths of the veins on the lateral leaves, and this is a diagnostic feature of great value (Fig. 4).

Although, as described, only Goldings show symptoms of Mosaic, many other varieties are carriers, i.e. they can harbour the virus without showing symptoms. The most important carrier variety is the Fuggle, but in addition most of the Wye Seedlings and certain male hops also come into this category. Such carrier varieties are, of course, valuable for planting where Mosaic disease makes the growing of Goldings impossible, but if a grower is particularly anxious to maintain a good stock of Goldings, carrier varieties can be dangerous. Mosaic disease in such varieties can spread from them to neighbouring Goldings and this has undoubtedly caused a great deal of Mosaic infection on many farms. It is advisable, therefore, to grow carrier and susceptible varieties as far apart as possible.

The type of carrier which is perhaps the most dangerous is the male plant that contains the disease. Many cases have been seen where carrier males have been planted in Golding yards and have there infected large patches of plants while themselves remaining apparently normal (Fig. 5). The only cure for this, of course, is the planting of males which cannot carry Mosaic disease. Such males have been selected at East Malling and are now available in small quantities for growers who wish to use them.

As with Nettlehead, nothing is as yet known about the vectors of Mosaic disease and this subject is now being studied.

Split Leaf Blotch.

This disease has recently been shown to be graft-transmissible. It is very widespread in many hop-growing areas and if severe can cause considerable stunting of the plants and loss of crop. The main symptom is a characteristic yellow blotching of the leaves. These yellow blotches become thin and oily in appearance and then die or split, causing the leaf to become very distorted. The bines do not fall from the string. The early symptoms of Split Leaf Blotch resemble those of Nettlehead, as the affected hills produce only a few sparse bines—so-called " spidery " stocks—but the leaf curl symptom of Nettlehead is absent.

It is difficult to assess the total damage caused by Split Leaf Blotch, but it is probably fairly considerable and it is certainly advisable that badly affected plants should be removed as soon as possible. The disease may be related in some way to Nettlehead, but this is not yet determined.

Other Diseases.

Chlorotic disease has been found occasionally in several localities, but rarely causes very much damage. It is a virus disease and is distinguished by the bright yellow markings on the leaves which curl downwards in a " parrot-beak " fashion.

Another disease that may be of virus nature is *Leaf Curl* ; it was very prevalent in 1947, and the main symptom is a very pronounced downward curling of the leaves, which turn dark green. This disease is probably associated with others that occur sporadically in most hop areas and are characterized by yellow blotches or dead patches on the leaves, but about which nothing is as yet known.

A further disorder which is often very common is *Fluffy Tip*. The tips of the bines stand away from the string and become stiff and short-jointed. Usually the bines grow out of this condition, which is probably due to adverse weather, but occasionally affected bines die and in this case it is possible that some virus disease is present.

Future Research Work.

The method of spread of hop viruses in England is not known and it is imperative that it shall be found out, for at present the only control methods which can be recommended are roguing and the use of clean sets. In spite of this the viruses remain a very real menace.

The three methods of spread of the viruses will be considered individually.

The only case of mechanical spread which has so far been demonstrated in hops is in Chlorotic disease, which is rare and spreads slowly in the field.

Grafting is apparently rare in the field. Natural grafts above the ground have not been reported and Beard, in his root studies on hops, did not find a single case of root grafting. Further root studies this year have not brought to light any natural grafting below ground. So it is possible that the spread of virus diseases in the field may be due to insects, and the main experiment in 1948 was to test the Hop Aphid as a possible vector.

The aphid was used with Nettlehead disease and Mosaic disease. Fuggle plants were used in the nettlehead experiments and Eastwell Goldings in the Mosaic experiments. The numbers of insects per plant were varied and a test was made for persistence and non-persistence of the virus. The aphids were collected in May and transferred to hops as soon as they had formed wings. When sufficient had been bred on the hops they were transferred to the diseased plants and then again transferred with a paint brush to the healthy plants which were used as indicators. In the first experiment 5 aphids on each plant were used. In the second experiment there were 50 aphids on each plant, and in the third experiment as many as 200 aphids were used on each plant.

Persistence and non-persistence of viruses in their insect vectors has been demonstrated with other virus diseases. When the virus is persistent the insect can take it up from the diseased plant, and remains infective for a long time. When a virus is non-persistent the insect can take it up in a short time and can immediately pass it on to another plant, but it has been found that the insects are more infective if they are given one hour of starvation before feeding on the infected plant. In this experiment, therefore, some insects were given long feeding periods and others starvation periods before feeding. Keyworth with Nettlehead, and Salmon with Chlorotic disease, reported few symptoms in the test plants until the year following the inoculation or grafting, so since no recognizable symptoms of Nettlehead or Mosaic were found in 1948 the plants will be kept under observation for the next three years to make sure that if there are symptoms showing in the future they will be found. During 1948, specimens of all four virus diseases were collected, and so there were available for 1949 more sources of disease than there were in 1948. More insects will be tried out on these four viruses and if the plants show no symptoms during the growing season they will all be planted out in the experimental garden and the search will be continued. It is intended to try the following possible vectors : the winged stage of the Hop Aphid, the Hop Red Spider, the Hop Flea Beetle, the Peach Aphid and eelworms, and as many more as there are time and space to investigate.

Other lines of investigation will now be discussed.

(i) *Hedgerow effect*. By digging into the site of the hedgerow effect it was discovered that there had been a ditch and a hedge. The ditch was still a watercourse, so it is necessary to find out whether the hedge or the ditch is responsible for the high incidence of Nettlehead on that site. Trenches will be made at East Malling and the soil from that site will be compared with Malling soil inside the trenches.

Two other comparisons will be made, free and impeded drainage and the growth of healthy and Nettlehead diseased plants.

(ii) *Pasture effect.* A record of diseases occurring on six acres of newly ploughed pasture, planted with hops three years ago, has been made. It showed that, although there were only about 30 Nettlehead diseased plants at that time, there was a large number of plants infected with Split Leaf Blotch and various mottles and other little-known symptoms. These have all been recorded carefully and will be observed in subsequent years to find out whether some of the symptoms are early Nettlehead characters or whether Nettlehead is independent of these other conditions.

(iii) *Persistent outbreaks of Nettlehead near hedges.* As Nettlehead often occurs near hedgerows at the edges of hop yards there may be alternative hosts of the virus in these hedges. The plants in the hedgerows on these sites will be investigated and an attempt made to find out whether they are capable of carrying the virus and then whether they are capable of giving it back to the hops. It is easier to test the ability of a plant to carry the virus than it is to find a plant which is already diseased in its natural surroundings. If it is possible to infect any plant from the hedge with Nettlehead, then a search can be made for naturally infected specimens of it.

(iv) *Virus complexes.* It is possible that Nettlehead and Mosaic are virus complexes. Since the vectors of these diseases are not known, it is not possible to separate the component parts of a complex, but the problem can be tackled in another way, by trying to build up the complex from its component parts. The collection of plants has already been made and in this material some of the individuals have definite virus symptoms. Other symptoms which may be caused by viruses have been found. Examples of these are : the small hop, small outgrowths (enations) on the leaf, and ring spots. Plants affected by these together with the known virus diseases Split Leaf Blotch and Chlorotic disease will all be inarched to one healthy hop which will be watched to see if it will produce recognizable symptoms of a known disease.

In this work the co-operation of hop growers will be of great value. There are almost certainly many symptoms and other correlations like the hedgerow effect about which nothing is as yet known. It would be a great help to the research workers at East Malling if those who are working in the field would report any strange symptoms on plants near any of their hops and any correlations they notice between diseases and conditions or sites.

2. Fungal Diseases.

Verticillium Wilt.

This disease exists in two forms, one, the fluctuating form, which is very mild and occurs in most hop-growing districts, the other, progressive, which is severe and at present is found in Kent and Sussex only. The fluctuating type was first discovered in 1924 in a Kentish hop yard, but the progressive type was not seen until about 1932.

Both forms of the disease are caused by the fungus *Verticillium albo-atrum*, a mild strain of which causes the fluctuating type and a virulent strain of which causes the progressive type. This fungus lives in the soil and infects the hop plants through their roots, afterwards growing in the woody tissue.

Since it was first noted in 1932, the progressive type of the disease has spread until it is now present on over one hundred farms. Outbreaks usually start with one or two plants which show, first, yellowing of the lower leaves and then gradual death of more and more leaves on the bines until eventually the whole plant is dead. The affected leaves fall off and are carried about by cultivators or blown in the wind. As they contain the fungus, the disease is thus spread about both within affected farms and to neighbouring yards. A typical severe outbreak is shown in Fig. 6.

Symptoms of the fluctuating type are much milder and often consist only of the swelling of the bine without any discoloration of the leaves. The wood inside the swollen bines is brown and as with the progressive type this constitutes the most reliable diagnostic feature. In addition to the thickening of the bines, some wilting may occasionally be observed on affected plants, but such plants are rarely killed by the disease. It is probable that this form of the disease is often derived from potatoes that have previously been planted in the yard, as this crop is also liable to *Verticillium* Wilt. A number of such cases have been seen in the West Midlands.

The reason for the difference between the two types of Wilt was obscure for many years, but it was shown to be due to differences in the virulence of strains of *Verticillium* by soil inoculation experiments, which were made in 1944. These experiments have since been extended and it now seems probable that the progressive strain arose about 1930 at one farm in Kent as a " mutant " of the fluctuating strain. It is thus, of course, always conceivable that the fluctuating strain may change into the progressive strain elsewhere, but it is unlikely that this would be of frequent occurrence.

Fig. 1.
Fuggle plant showing severe Nettlehead.

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FIG. 2*a*.

Site of old hedgerow made clearly visible from the air by the great number of Nettlehead and missing plants along it.

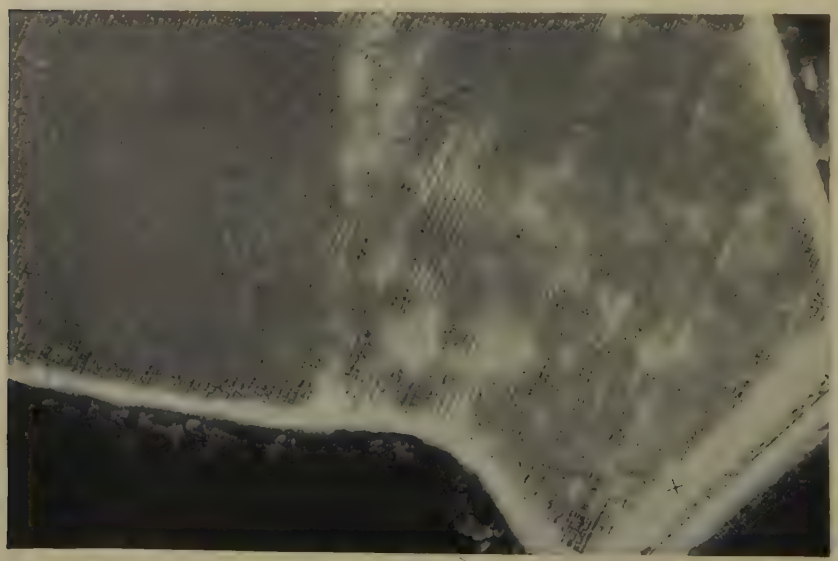

FIG. 2*b*.

Part of a hop garden showing the clear distinction between an old pasture and an old arable section. The former contains 10 per cent. Nettlehead plants—the latter contains only 0·5 per cent. of such plants.

FIG. 3.
Golding plant showing severe Mosaic disease.

FIG. 4.
Healthy and mosaic-affected leaves. Note cleared lengths of veins on latter.

FIG. 5.
Mosaic carrier male plant in the centre of a mosaic area in a Golding yard.

FIG. 6.
Severe outbreak of Progressive *Verticillium* Wilt.

FIG. 7.

Three wilt-resistant plants and a Fuggle plant growing in heavily infected soil. Note the vigour of the resistant plants and the dead Fuggle.

As the progressive strain has caused tremendous damage to many Kentish hop farms, it has naturally received priority of attention in the research work. In the early years attempts were made to control it by use of hygienic precautions designed to remove infected debris, but these, while alleviating the disease to some extent, did not provide an adequate control. Fallowing experiments were also made and it was shown that up to four years without hops did not greatly reduce disease incidence, but that seven years fallow may perhaps eliminate the disease. Similarly, soil disinfection by means of formalin or other chemicals was of value for small outbreaks, but impracticable in many cases.

Attention was therefore concentrated on the discovery of varieties resistant to the disease. As all the commercial varieties were found to be susceptible, tests were started on the new Wye Seedlings bred by Professor Salmon. Fortunately, some of these were found to possess reasonably high resistance (Fig. 7), although none has yet been found that is completely immune to the disease. Intensive tests of several of these varieties have now been made on many farms and as a result the two varieties OR55 and OJ47 have been selected as possessing both reasonably high resistance and good cropping power. These two varieties are now being tested at breweries in many parts of the country and up to date appear to be acceptable to a large number of them. Resistance trials of other varieties are still proceeding, of course, and several newer selections are now being tested. In addition to this, new breeding work has been carried on for several years and this too is providing some quite promising varieties that may be of value if the first selections are unacceptable for any reason.

There thus seems to be a reasonable prospect of a control of this disease by these means.

Fundamental studies on Wilt are also being undertaken. It has been found that manurial effects play some part in determining the severity of the attack, but these results do not as yet indicate any practical control measures. The effects are still being studied, as are also the basic causes of resistance.

Certain Other Fungal Diseases.

Phytophthora Root Rot has been known in New Zealand for some years, but has only recently been identified in Great Britain. It causes a rapid yellowing of the leaves and wilting of the bines, usually during August. The wood at the base of infected bines is a dark uneven brown in colour, and this discoloration extends into the roots. The cortex of the basal portions of the bines and of the roots may also be black and rotted.

This disease was first recorded on the variety Brewers Gold, but was subsequently found to be widespread on the common commercial varieties (Fuggles and Goldings). On these, however, it causes only very mild symptoms, an effect that has doubtless led to its confusion with other diseases. It appears difficult to control this disease on those varieties that are badly affected and it is possible that it may limit their use in certain yards. Further work on the disease is in progress.

Armillaria Root Rot is present in many yards, particularly where hops have been planted on the site of a grubbed orchard or hedgerow. The disease is easily identified by the presence in the rootstock of a mass of white fungal strands, smelling of mushrooms, and it causes a general rotting of the bases of the bines with subsequent wilting and death. Control of this disease is difficult but replantings have been successful after the removal of infected tree and hop roots and the treatment of the soil with formalin.

Canker caused by the fungus *Fusarium* is very common in all hop-growing areas, particularly on Goldings, where it can cause considerable damage. It is generally characterized by the wilting of odd bines here and there in the yard due to the rotting of their bases by the fungus. This rotting causes the bines to taper off to a very typical " pencil-point " sometimes termed " growing off ". A form of this disease which has been fairly prevalent recently is " High Canker " (Stem Canker), caused by the same fungus which instead of rotting the bases of the bines has entered through a leaf scar. Here it causes a black lesion some three or four inches long, situated about one foot above the soil level. Above this lesion the bine becomes very swollen and corky and at first sight resembles *Verticillium* Wilt. Affected bines usually wilt off just before or during picking, and the disease can cause some considerable loss of crop. No control measures are at present known, but it would seem advisable to ensure that leaf stripping is done without tearing of the bine, so that the fungus has less chances of entry.

Summary.

This is a popular account of the hop diseases being studied at East Malling Research Station. These include *Verticillium* Wilt and the virus diseases Nettlehead, Mosaic and Split Leaf Blotch.

Past work and future programmes are described and a brief discussion on viruses is included.

FRUIT MARKETING TODAY

By A. C. PAINTER

During the greater part of the war and in the years immediately following, practically the only fruit available was that grown in the country. Prices were strictly controlled and with demand usually much in excess of supply the great bulk of the fruit, whether good or bad, tended to fetch the same maximum price.

The position is now radically changing. In the case of soft and stone fruits, controls have been removed altogether. With hard fruits they have been lifted from time to time and then reimposed. Most important of all, imports are being permitted to an ever increasing extent. During the present season quantities of apples and pears have arrived from abroad at a time when there have been large supplies of home-grown produce in the markets. This has resulted in severe competition between home-grown and imported fruits.

While there are many factors, the effect of which it is hard to assess under the changing conditions of today, the past season has been a sharp reminder of what was realized before the war, but in the intervening years has been largely lost sight of ; that in years when fruit is plentiful, whether this is due to a heavy crop of home-grown fruit or to imports, or both, only good quality fruit that has been well graded and suitably packed is likely to sell at an economic price.

Take apples as an example ; in view of the prospective heavy crop of early cooking varieties those with experience of marketing before the war were quite prepared for a substantial drop in prices once the bulk of the crop came on to the market, but neither the market nor the growers anticipated the extent of the fall that actually took place.

Quite early in August the price of small cooking apples, which started off at the controlled price of 15s. a bushel, had dropped to as low as 1s. a bushel and subsequently dropped to 6d. In contrast to this, fruit over 3 in. in size was fetching up to 8s. and 10s. a bushel quite late in the month.

Dessert apples were easier to sell but here again there was a marked disparity in price between good and poor fruit, and more especially between large and small fruit. At East Malling " Fancy " grade Worcesters of $2\frac{1}{2}$ to $2\frac{3}{4}$ in. fetched up to 28s. a bushel, but 2 in. fruit, though otherwise of the same quality, marketed at the same time, only made round about 4s. to 7s. a bushel. The difference in price between large and small Cox was far less marked. Fruit of Ellison's Orange, Charles Ross and Rival of $2\frac{1}{2}$ in. and upwards moved readily at prices ranging from 20s. to 30s. a bushel.

By the time late cooking apples came along there was rather less fruit about and " Fancy " Bramleys over 3 in. in size reached 20s. a bushel ; small fruit, however, still fetched little.

All through there has been this striking difference between the price for large fruit and the price for small fruit. This difference has been much greater than was experienced before the war.

If this is any criterion of what to expect in the future, what can the fruit grower do about it ? Probably a good deal, and the following are a few suggestions.

1. He must, of course, grow fruit free of damage from pest and disease. There is no need to dwell on this. Research has provided an adequate spraying programme and other means by which the grower can achieve this end in a normal season.

2. He must grow fruit of a size that will sell readily. With most dessert varieties the apple that sells best on the market is normally the $2\frac{1}{2}$ to $2\frac{3}{4}$ in. size, i.e. apples that go 163, 175 or 188 to the 40 lb. box, or say 4 to $4\frac{1}{2}$ to the lb. Early sorts, such as Beauty of Bath and Cox, can be slightly smaller, say $4\frac{1}{2}$ to 5 to the lb.

The size of cooking apple that usually sells most readily is one of about 3 to $3\frac{1}{2}$ in., which goes 96, 104 or 112 to the 40 lb. box, or say $2\frac{1}{2}$ to $2\frac{3}{4}$ to the lb.

If the best economic results are to be obtained it is necessary for the bulk of the fruit to be round about these sizes. As trees grow older, fruit size tends to decrease and, unless growing conditions are exceptionally good, with most varieties much of the fruit is likely to fall below the best size. Should this happen then such steps as are possible should be taken to remedy it. There are three obvious ways that suggest themselves, viz. (1) pruning, (2) manuring, and (3) fruit thinning.

Pruning.

Fruit size can be increased by reducing the number of fruit buds on a tree at time of pruning. This can be done by thinning out the fruit spurs, shortening laterals and removing individual fruit buds by cutting them out or by bud rubbing ; sometimes whole branches can be removed with

advantage. This is most effective where branches and fruiting spurs, or both, have been allowed to grow too thickly, or where there is abundance of blossom bud. Those who are not certain as to the best treatment will find much to help them in Ministry Bulletin 133, *Apples and Pears*, pages 52 to 60 and 85 to 86.

Manuring.

Manuring by means of organic and inorganic manures should be considered.

Sometimes the required fruit size can be obtained by manuring alone, but it must be remembered that heavy nitrogenous manuring tends :

(1) to reduce fruit colour, an important factor where dessert fruit is concerned ;
(2) to make the fruit softer, and so more easily bruised ;
(3) to affect keeping quality adversely.

Fruit Thinning.

Thinning, used in conjunction with pruning and manuring, is probably the most effective means of regulating fruit size. Besides improving colour and reducing the number of cull fruits, it has the advantage of producing fruit of more even size than would pruning and manuring alone. It also reduces the number of individual apples that have to be handled at picking and when grading and packing the fruit for market, quite an important consideration when a large quantity of fruit has to be dealt with.

It is recognized that an extensive thinning programme may be exceedingly difficult to carry out under existing labour conditions, but the fact has to be faced that in a season such as the past small fruit simply will not sell.

To get the best results thinning must be early and sufficiently drastic. Even with Cox there is evidence to show that thinning can safely be done before the June drop. With the ordinary run of commercial apple there is seldom any danger of getting fruit of too big a size. In any case big fruit sells much better than small.

Special Considerations.

Early Cooking Apples.—With things as they are at present it is essential in a normal season to get a good-sized fruit as early as possible—with Early Victoria the aim should be to get fruit of sufficient size to start picking about the middle of July and to enable the bulk of the fruit to be cleared by August Bank Holiday. To do this thinning to 9 in. apart is none too much, and should be started early.

Similarly the bulk of the Grenadier crop will usually want clearing by about the third week in August. At that time the fruit should be 3 in. or over to sell at all readily. Spacing the fruit to an average of 6 in., with generous manuring, usually suffices.

If lack of labour or other reasons do not allow of this sort of programme, such varieties are best reduced to a minimum.

Lord Derby.—This is another variety where it is necessary to produce a large-sized apple (over 3 in.) as early as possible. This is normally done by generous manuring and thinning, up to 9 in. apart. If this cannot be done, commitments in respect of this variety are best reduced.

Worcester Pearmain.—The apple the market likes is one between $2\frac{1}{2}$ to $2\frac{3}{4}$ in. in diameter. Unless growing conditions are really good, it is seldom possible with mature trees to get a good proportion of the fruits of this size without thinning (say from 4 to 6 in. apart), especially as there would seem to be a limit to the amount of nitrogen that can be advantageously applied. It is generally agreed that the best Worcesters are grown under slightly starved conditions.

Cox's Orange Pippin.—The $2\frac{1}{2}$ to $2\frac{3}{4}$ in. apple sells best, but it is perhaps not so important to get a good-sized apple because even small fruit of about 2 in. sells reasonably well ; there is nothing like the same difference in price between large and small fruit as there is in the case of Worcester. There is no doubt, however, that both fruit size and quality can be appreciably improved by thinning. As a rule spacing the fruit from 4 to 6 in. apart should be sufficient. As already stated there is evidence to show that Cox can be safely thinned before the June drop.

Late Cooking Apples.—Thinning large Bramley trees is a difficult proposition and most growers will probably have to rely on improving fruit size by maintaining a high level of nutrition. Thinning, where it can be done, however, will greatly help those who have no refrigerated storage and must perforce market the bulk of the crop before Christmas, for when fruit is plentiful only apples over 3 in. in size are likely to fetch a reasonable price.

The production of good-sized fruit, though advantageous, is not so important to the grower with refrigerated storage, as he can hold over his small fruit until the spring, when it normally commands an economic price.

Grading and Packing.

During the war years and those immediately following, lack of labour, scarcity of packing material and absence of competition led to little being done in the way of either grading or packing. If, however, the grower is to compete successfully with imports, as the past season has emphasized, not only must he grow good fruit but he must grade it and present it as well as he can with the limited means at his disposal. All reports received from the market during the past season indicated that grading and wrapping made all the difference to the sale of the fruit. One point should, however, be emphasized and that is that fruit must reach a certain standard to make grading and wrapping worth while. As the season went on appreciable quantities of inferior fruit have been wrapped apparently in the hope that it would thereby fetch a higher price. To help the grower the Ministry of Agriculture, in conjunction with the Industry, have drawn up suggested grade standards for apples, pears and certain other fruits, which growers are being asked to try out. Particulars can be obtained from the Ministry, Marketing Division, 36-38 Chester Terrace, Regent's Park, London, N.W.1.

One last point : there is nothing that can so quickly spoil the appearance and depreciate the value of fruit as bruising, and anything that can be done to increase its hardness would seem worth considering. Apples from grass are normally harder textured and less easy to bruise than fruit from cultivated ground, and the grower of varieties that bruise easily might well consider whether such could not with advantage be grassed down.

Careless handling and consequent bruising must be guarded against from the time the fruit is being picked until it leaves the grower's hands, that is during the process of picking, whilst it is being transported to the packing shed, whilst it is being graded and packed and finally when it is being loaded for despatch to the market.

Only apples have been dealt with in this review, but the same principles apply to all other kinds of fruit if the grower is to compete successfully in the market when fruit is plentiful.

Summary.

The marketing position is briefly reviewed. Attention is drawn to the need for growing good quality fruit if an economic price is to be obtained. Some ways and means of improving market quality are suggested.

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